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THE UNIVERSITY OF ALBERTA

THE EFFECT OF THERMAL EFFLUENT UPON AN EPIPHYTIC ALGAL COMMUNITY IN LAKE WABAMUN, ALBERTA

by

© DAVID M. KLARER

A THESIS
SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH
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DEPARTMENT OF BOTANY

EDMONTON, ALBERTA
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THE UNIVERSITY OF ALBERTA

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled "The Effect of Thermal Effluent Upon an Epiphytic Algal Community in Lake Wabamun, Alberta" submitted by David M. Klarer in partial fulfilment of the requirements for the degree of Master of Science in Algal Ecology.

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Date September 10, 1973

ABSTRACT

The investigation of the epiphyton attached to *Scirpus validus* Vahl. at Lake Wabamun, Alberta, commenced in early May, 1971 and continued until the end of August 1972. Seven sites, encompassing both heated and non-heated zones in the Sundance and Wabamun Power Plant areas were selected for this study. From July, 1971, until the termination of the study, water temperature and water chemistry were monitored. With the exception of temperature and dissolved oxygen levels there were no large variations in these parameters between the heated and non-heated sites.

The epiphyton at all sites showed a spring maximum, a summer minimum, and another large maximum in late summer/early autumn. The spring dominants at all sites were *Fragilaria capucina* and *Diatoma elongatum*. During the late summer/early autumn peak, however, diatoms were dominant in the non-heated sites while chlorophycean species were dominant in the heated sites.

The thermal effluent caused a decrease in the number of species and a corresponding increase in the importance of a few species in the heated sites. The major impact of the effluent, however, was an extension of the period of open water and the corresponding increase in mean yearly standing crop size in the affected areas.

Many of the major species displayed a preference for either the heated or non-heated areas. The ultimate cause of this preference was the influx of thermal effluent although the direct cause was often not a temperature preference.

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INTRODUCTION

The increasing demands for electricity have led to the construction of many new power stations. These stations often use either a river (WAPORA, 1971) or a lake (Nursall and Gallup, 1971; Whitehouse, 1971) for the dissipation of the excess generated heat which has caused environmental changes in these natural water systems (Cairns, 1956; Cairns, Lanza, and Parker, 1972). Although the effects of increased temperatures have been the source of intense study (Coutant, 1971; Coutant and Goodyear, 1972), the effects on naturally occurring benthic algal communities have generally been ignored.

The epiphytic algal community provides an excellent biological indicator of any changes in the ecosystem since the algal components of this community are fixed and thus, unlike the phytoplankton, are unable to be moved out of the affected areas. Therefore if changes in the environment are caused by the thermal discharge of the two power stations at Lake Wabamun these changes should be reflected by changes in the epiphyton. However, before these changes can be detected it is necessary to determine the normal seasonal succession, species composition, and changes in standing crop size of the epiphyton in unaffected areas of the lake.

The purpose of this study was to record any changes in an epiphytic algal community caused by thermal effluent through a comparison of the seasonal succession, species composition, and standing crop in heated and non-heated areas. The standing crop was determined using chlorophyll a content, total cell numbers, and calculated total cell volume. Both seasonal succession and species composition were determined from total cell numbers.

Terminology

The division of the algal benthos into its separate member communities has long been a source of confusion (Young 1945, Cooke 1956, Wetzel 1964, Round 1964). Seligo (1905) introduced the term "Aufwuchs" to include the whole sessile benthic community. "Bewuchs" was introduced in 1915 to characterize those organisms that grow attached to artificial submerged surfaces (Hentschel, 1915). Almost immediately this term was expanded to encompass all organisms that grow attached to dead surfaces, while Aufwuchs was redefined to include only those organisms that grow attached to a living host (Hentschel, 1915). The term periphyton was introduced to refer to organisms growing attached to artificial surfaces (Behning, 1928). Young (1945), following the definition proposed by Roll (1939), considered periphyton to be the "assemblage of organisms growing upon free surfaces of submerged objects in water, and covering them with a slimy coat". Wetzel (1964) similarily defined periphyton to include all sessile organisms with the exception of rooted macrophytes. Round (1956) stated that the term periphyton was superfluous and should be discarded because, by etymology, it signifies a peripheral existence and many of the communities it is used to describe are not peripheral.

The term epiphyton has long been used to designate those organisms growing attached to macrophytes, whether submerged or terrestrial. Cooke (1956) considered epiphyton to include only those organisms that grow attached to terrestrial macrophytes, while the term periphyton included the organisms growing attached to submerged macrophytes. Abdin (1949) used epiphyton and periphyton interchangeably with both referring to organisms that colonize any submerged surface while Round (1956), considered epiphyton to include only the organisms that grow attached to macrophytes or other algae. Wetzel (1964) reinforced this definition by using the term epiphyte to refer to those organisms attached to higher plants. However, he used the term only as an adjective to modify and restrict the term periphyton - i.e. epiphytic periphyton. Foerster and Schlichting (1965) coined the term phyco-periphyton to describe the "assemblage of algae growing on or in close proximity to submerged plant materials".

The term epiphyton will be used in this thesis to describe the algae that grow attached to submerged macrophytes (Round 1956, 1964, Round & Hickman, 1971) while the term periphyton will be used to designate those algae that colonize artificial surfaces.

LITERATURE REVIEW

Attached Algae

Most of the studies concerning attached algae have been qualitative rather than quantitative due primarily to the many problems associated with the latter (Sládečková, 1962). Also, the majority of studies have been ecological. Edsbagge, (1968 a & b) examined the physical and biological factors that influenced the diatom distribution on seaweeds. Pieczynska (1968) studied the effects of vertical distribution on the productivity of algae scraped from *Phragmites* sp. while Szczepanska (1970) used algae removed from *Phragmites* sp. in six different lakes to examine the role of epiphyton in determining the trophic level of a lake. Jørgensen (1957) also used the epiphyton of *Phragmites* sp. in his study on the role of silica in diatom periodicity. Knudson (1957) quantitatively removed *Tabellaria flocculosa* (Roth.) Kütz. from *Phragmites* sp. for periodicity studies by shaking. Young (1945) examined the seasonal succession of the epiphytes attached to *Scirpus* sp. Hickman (1971) studied the seasonal succession and primary productivity of the epiphyton attached to *Equisetum fluviatile* L. Assman (1951, 1953) studied the in situ productivity of the epiphyton attached to *Equisetum* sp. using a modified oxygen technique. Therefore, most epiphyton studies have involved a host macrophyte of simple growth form so that removal and subsequent determination of host surface area was a simple procedure. However, quantitative studies of the epiphyton attached to macrophytes of a more complex morphology have been conducted. Douglas (1958) studied the epiphyton attached to submerged moss by grinding up the host and associated epiphytes and then counting the algae. Tippett (1969) removed the epiphytes from various aquatic macrophytes with heated HCl for seasonal succession studies of diatoms. Sládečková (1962) mentioned, in her review of methods for study of attached communities, that direct microscopic observation of the epiphyton attached to macrophytes can be conducted on macrophytes with thin, nearly transparent leaves. She also suggested that direct observation could be made on other plants by carefully removing strips of epidermis from the host plant. This method is very impractical, however, on plants that have other than a simple growth form.

Due to the large variability in the texture and nature of natural surfaces (Grzenda and Brehmer, 1960) and the problems encountered with the quantitative removal of epiphyton from natural hosts (Sládečková, 1962), many workers have turned to using artificial substrata when studying attached algal communities. Cooke (1956) and Hohn (1966) have reviewed the use of artificial substrata in the study of algal periphyton. Quantitative studies using artificial surfaces (usually glass slides) have been utilized for standing crop determination and primary productivity (Sládecek and Sládečková, 1964, Wetzel, 1964, 1965, Milovanović and Petković, 1968, Allen, 1971, and Brown and Austin, 1973) and for seasonal succession (Abdin, 1949). Dickman (1969) used periphyton as a biological indicator of water pollution.

The texture of the substrata, whether natural or artificial, influences the structure and composition of the attached algal community. Edsbagge (1968b) has found that some seaweeds have their own diatom flora. This natural substrate affinity has not been demonstrated for freshwater epiphytes, although it probably exists.

Early workers (Sládečková, 1962) concluded that the texture of the artificial surfaces made little difference in the periphyton composition. As a result of this early work, most periphyton studies employed glass slides as the substrata due to the ease and accuracy in removal obtained with the slides. Recently workers have been questioning the validity of these early conclusions. Harper and Harper (1967) found that diatoms adhered more strongly to glass than they did to plastics, while Hohn and Hellerman (1963) found that in cold water styrofoam supported a more representative population than did glass.

A significant difference in both the composition and density exists between the flora attached to a horizontal surface and that attached to a vertical surface. Newcombe (1949) found that a horizontal surface may collect up to 6 times the organic matter found attached to a vertical surface. Sládečková (1962) reported that a horizontal surface would collect a great amount of debris besides the true periphyton. Also light could become a limiting factor on the lower surface if a horizontal glass plate were incubated for a long enough time due to the large amount of debris collected on the upper surface. In such a situation, the upper surface of the plate would be characterized by autotrophic organisms, while the lower surface would be dominated by heterotrophic organisms. The vertical surface collects less debris and the two sides have similar populations, although the periphyton require a longer colonization time.

It has been stated that the glass slide collects only live diatoms (Patrick, Hohn, and Wallace, 1954), and thus becomes a good tool for study of the viable population. Owen (1960), however, found that over 30% of the diatoms attached to his glass slides were dead at the time of collection. As the incubation period was only 2 weeks, he concluded that most of the empty frustules had been empty at the time they came in contact with the slide.

A major consideration in the use of artificial substrata for evaluation of attached algal communities is the magnitude of planktonic species trapped by the substrata. Brown and Austin (1973) reported that *Fragilaria crotonensis* Kitton, a planktonic diatom, was a major component of the periphyton. Hohn (1966), however, concluded that less than 5% of the population collected on slides suspended in Lake Erie were planktonic species.

Only recently have workers begun to compare the periphyton with the natural attached algal communities. Patrick et al. (1954) and Brown and Austin (1971, 1973), have found the communities growing on artificial surfaces and on the natural substrata to be very similar. However, Foerster et al. (1965) reported that glass slides supported a smaller diversity of diatoms than the natural substrata as well as a reduction in the diversity of the green and blue-green algae. They also found that the periphyton seasonal maximum did not correspond to the epiphyton maximum. Tippett (1969, 1970) was the first to compare the seasonal succession of various diatom species on both natural and artificial surfaces. He found that the periphyton displayed a distinct seasonal succession but it was not related to that shown by the epiphyton. The diversity of diatom species found on glass slides was much smaller than on surrounding macrophytes due to the failure of some of the rarer species to inoculate the slides, and also to the inability of some species to colonize the glass slides. The artificial surface altered the growth periods of several of the diatom species, some were lengthened and others were shortened. From this work, Tippett (1970) concluded that as the diatoms were affected by the artificial substrata in an unpredictable fashion, periphyton was unreliable as an ecological indicator.

From this it can be seen that the texture and position of the substrata can affect the resulting population. In comparing populations of algae on artificial and natural substrata, it has been demonstrated that the periphyton can be unreliable in predicting the seasonal patterns of epiphyton. For this reason, no studies with artificial surfaces were attempted in this work.

Effects of Thermal Effluent on Algal Communities

Cairns, Lanza, and Parker (1972) have proposed that pollution includes "any change in the environment for which a species or community has inadequate information and thus is incapable of an appropriate response". Changes in algal species diversity have been demonstrated as an effective biological method of pollution detection. Thienemann (1939) proposed than an unpolluted environment would be characterized by many different algal species, each of which would have a relatively small population. Patrick et al. (1954) postulated that any pollution stress causes a decrease in the number of species and a subsequent increase in abundance of the more tolerant species. The effect of pollution is to eliminate many of the more sensitive species. Cairns (1956) believed that due to the strong competition that exists for space, a species may be eliminated by an unfavorable rather than a lethal factor. The competition is reduced with the elimination of many of these sensitive species, thus the more tolerant species are able to spread out and occupy larger areas. If thermal effluent is a pollutant, then the affected algal communities should show an expected decrease in diversity, as was shown in the studies of Owen (1960).

A temperature increase causes a decrease in the 100% dissolved oxygen saturation level and at the same time causes an increase in the metabolic rate of the affected organisms. These two factors enhance the possibility of an oxygen depletion in the heated water (Phinney and McIntire, 1965).

Cairns (1956) found that temperature gradients existed in algal populations, from 20^0 - 30^0C diatoms were dominant, from 30 - 35^0C members of the Chlorophyta were dominant, and above 35^0C members of Cyanophyta were the dominant algae. However, some members of each group survived even when their optimum temperature had been exceeded, because as the temperature was gradually lowered back down from 40^0C, members of the Chlorophyta and then the diatoms reappeared to become the dominants again at their respective optimum temperatures. Wallace (1955) supported this contention by showing that even at temperatures when most of the cells in unialgal cultures were killed by excess heat, there were still some cells that were heat-resistant and still viable.

Several workers have found the abundance of diatoms in the flora is inversely related to water temperature (Patrick et al, 1969, Coutant, 1971). High water temperatures favored the growth of the chlorococcalean cyanophycean algae and desmids. In warm waters, a high oxygen level favored members of Chlorophyta, while a low oxygen and high organic level favored the Cyanophyta. Owen (1960) reported that thermal effluent favored the growth of Cyanophyta and diatoms of the Family Fragilariaceae, while all other algae were reduced in numbers. However, the effects of thermal discharges on algal populations are dependent upon the other environmental conditions, and unless these conditions are known, the specific results of the addition of heated water are unpredictable. Whitehouse (1971) found that the effects of heated water were overridden by a lack of nutrients in an oligotrophic lake, WAPORA (1971), in a study of the Ohio River, found that thermal discharges had no measurable effects either on plankton composition or on primary productivity. North (1969) found a decrease in the number of seaweeds in the discharge canal of a power plant along the California coast, but reported there was no invasion of blue-green algae as might be expected. In a study done on Lake Michigan, there was a decrease of the attached algal communities in the thermally polluted areas (Cairns et al., 1972). Coutant (1966), in a study on a river found that the total attached algal population increased. Although all algal groups except the Cyanophyta showed a decrease in the affected areas, the increase in the Cyanophyta population was more than enough to offset this decrease with respect to total standing crop.

Morgan and Stross (1969) stated that the photosynthetic rate in phytoplankton increased with increasing temperature until a maximum rate was attained. Any increase above this temperature caused a severe reduction in photosynthesis, which was irreversible. In a study done on Long Island Sound, the temperature increase generated by a thermal discharge caused a photosynthetic decrease, although there was very little change recorded in either species number or diversity in the heated area (Coutant and Goodyear, 1972). A possible cause of this rapid decrease in photosynthesis could be the instability of chlorophyll at high temperatures. Lanza and Cairns (1972) have found that several accessory carotenoid pigments are damaged under thermal stress.

Several morphological features, particularly cell size, have been shown to vary in response to changing temperatures (Coutant and Goodyear, 1972). Cairns et al. (1972) have reported a suppressed cell division at temperatures near the high level of tolerance. Lanza and Cairns (1972) have found that abrupt thermal stresses on diatoms cause a decrease in cell lipid content possibly due to the disruption of the cell membrane. This lipid loss could delay or prevent cell division as reported above. The vertical migration of, particularly, the planktonic species could be disrupted as many diatoms use lipid droplets for altering specific gravity. Also, the decrease of lipid cell content would cause a decrease in the nutritive value of these diatoms and thus could have a profound effect on the food web.

Although the recent literature on the effects of thermal effluent on the biological communities has been prolific, there has not been enough work done to explain the many ramifications of the addition of heated water to a river or lake system. Only recently has work begun to examine the effect of heated water on the physiology of the affected algae and also on the algal community structure and dynamics.

AIMS OF THIS WORK

This work formed part of a larger study undertaken by the Departments of Zoology, Botany and Civil Engineering, University of Alberta, to examine the environmental consequences of discharging thermal effluent directly into Lake Wabamun. The purpose of this portion of the project was to determine the species composition, seasonal succession, and standing crop of an epiphytic algal community attached to *Scirpus validus* Vahl. and the effects of thermal effluent on this algal community.

METHODS

Field

General

The study commenced in the spring of 1971 after an intensive survey of the lake had been conducted to determine the most suitable areas for sampling stations. Duplicate samples were taken at fortnightly intervals from seven sampling stations from May 1971 through August 1972. These stations included both heated and non-heated sites in the Wabamun and Sundance Power Plant areas. During the ice-free months of the year, the sites were always sampled in the same order so that each station was sampled at approximately the same time each day. Through the winter and early spring, the four non-heated sites were inaccessible due to ice formation. These stations were shallow enough that the ice generally went down to the sediment surface. This, plus the destruction of the sedge stems by shifting ice early in the winter all but precluded any epiphytic population at these stations.

Physical

The weather conditions were recorded each sampling day. This information has been augmented with data obtained from the Department of the Environment weather stations at both Stoney Plain and the Edmonton Industrial Airport in order to obtain a more complete description of the meteorological conditions through the study period.

From July 1971 until the termination of the study, water temperatures and dissolved oxygen contents were determined at each of the sites at fortnightly intervals. Measurements were taken at 0.25 meter intervals from the water surface with a YSI Model 54 Oxygen-temperature Meter. Previous work (Gröterud, 1971) and present calibrations have shown that the thermistor varied less than 0.4°C from those taken with a mercury thermometer while the oxygen readings varied less than 0.5ppm from corresponding Winkler titration readings. The membrane on the oxygen probe was changed frequently to minimize algal and bacterial growth on its surface as the membrane had to be kept moist.

No light transmission measurements were taken due to the shallowness of all the stations. At no time during the study was it impossible to clearly see the sediment surface. However, turbidity readings were recorded for each of the stations. The Hach Kit turbidometer was utilized and the degree of turbidity was recorded in Jackson Turbidity Units.

Chemical

Water samples were collected at each site in one liter polythene bottles. Each bottle was rinsed once at the station before it was filled. The water samples were returned to the laboratory where they were immediately filtered through GF/A filter paper to remove algae, animals and detritus. The samples were then frozen until they could be analysed by the water chemistry technician, Mrs. G. Hutchinson. The following tests were conducted using procedures outlined in Standard Methods (1965).

Free Carbon Dioxide - Free Carbon Dioxide levels were calculated by means of a nomograph in Standard Methods (1965).

Alkalinity - Both phenol- and total alkalinity measurements were made titrimetrically. Total alkalinity was determined using bromcresol green-methyl red as the endpoint indicator and expressed as mg/l $CaCO_3$.

Hydrogen Ion Concentration - The hydrogen ion concentration (pH) was determined electometrically on a Fisher Accumet Model 220 pH Meter.

Hardness - Both calcium and total hardness content were determined using the EDTA titrimetric method.

Phosphate - Orthophosphate determination was conducted using the stannuous chloride method.

Nitrate - Nitrate nitrogen was measured using the phenoldisulfonic acid method.

Silica - The colorometric molybdosilicate method was used for silica determination.

Iron - Iron concentration was determined by the phenanthroline method.

Chloride - An argentometric titrimetric method was used for chloride determination.

Sulphate - Sulphate concentration was measured using a turbidimetric method in which the sulfate ion is precipitated as barium sulphate.

Fluoride - Fluoride concentration was determined with the Hach Kit. The test was very similar to the alizarin photometric method outlined in Standard Methods (1965).

Conductance - Specific conductance was measured using a Beckman Conductivity Meter.

Colour- Colour was determined by spectrophotometrically comparing the water sample against a curve of known values.

Filterable Dissolved Solids - Dissolved solids were determined by evaporating a known volume of water and weighing the residue.

During the summer of 1972 tests for potassium (colourimetric method) and manganese (persulphate method) were periodically conducted.

Biological

The method for sampling the *Scirpus validus* Vahl. stems along with the attached epiphyton involved the removal of the aerial portion of the stem before sliding a glass tube over the submerged portion (Hickman, 1971). The stem was initially cut approximately 15 centimeters below the surface of the water to minimize the effects of wave action on the sampled population. The portion of stem above this cut was discarded. After this initial cut, a glass tube (interior diameter 2.5cm) was carefully slipped over the desired portion of the stem. A second cut was then made 20 to 25 centimeters below the original cut. The glass tube was immediately sealed to prevent loss of attached algae from the sampled portion of stem and its surrounding water.

Laboratory

General

Immediately upon return to the laboratory, the water fraction containing the loosely attached epiphytes was drained off and diluted to a standard volume of 100ml. The *Scirpus* stem was then scraped with the blunt edge of a scalpel to remove the attached epiphyton. The epiphyton were scraped into a small volume of water which was then diluted to a standard volume of 100ml. The entire stem sample was systematically scraped several times to ensure complete removal of the epiphyton. Periodic examination of the scraped sedges showed that removal was complete. Hickman (1971) has shown that if the scraping is carefully done, the damage to the stems of *Equisetum* sp. is negligible. Microscopic examination showed that damage was also negligible with *Scirpus validus.*

Due to the cylindrical nature of the *Scirpus* sp. stem, the surface area of the host plant was easily determined. Attempts to correlate either sedge wet weight or dry weight with surface area were unsuccessful.

Chlorophyll a content

Sub-samples of 10mls or 25mls, depending upon population size, of the loosely attached epiphyton and the attached epiphyton samples were filtered through Whatman GF/C glass fiber filter paper. The filter papers and algae were then placed in 25 mls of 90% acetone to extract the pigment. The acetone was buffered with anhydrous magnesium carbonate to neutralize the extract and thus prevent the degradation of chlorophyll a to pheophytin a (Moss 1967a). The pigments were extracted at 3^o - 4^oC in the dark for 24 hours. Afterwards, extracts were centrifuged at 3,000rpm for 10 minutes to precipitate filter paper fibers, cellular components, and excess nondissolved magnesium carbonate, and then read at the following wave lengths: 750mμ (turbidity blank), 665mμ (chlorophyll a). 430mμ (chlorophyll a), and 410 mμ (pheophytin a). Afterwards each extraction was acidified with 10 drops of HCl and reread at 410mμ and 430mμ. This method, described by Moss (1967a,b) enabled the determination of naturally occurring pheophytin a, thus decreasing the possibility of overestimating the chlorophyll a content. Results were expressed in mg chlorophyll a/meter^2 *Scirpus* stem.

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Chlorophyll a content

Sub-samples of 10mls or 25mls, depending upon population size, of the loosely attached epiphyton and the attached epiphyton samples were filtered through Whatman GF/C glass fiber filter paper. The filter papers and algae were then placed in 25 mls of 90% acetone to extract the pigment. The acetone was buffered with anhydrous magnesium carbonate to neutralize the extract and thus prevent the degradation of chlorophyll a to pheophytin a (Moss 1967a). The pigments were extracted at 3° - 4°C in the dark for 24 hours. Afterwards, extracts were centrifuged at 3,000rpm for 10 minutes to precipitate filter paper fibers, cellular components, and excess nondissolved magnesium carbonate, and then read at the following wave lengths: 750mμ (turbidity blank), 665mμ (chlorophyll a). 430mμ (chlorophyll a), and 410 mμ (pheophytin a). Afterwards each extraction was acidified with 10 drops of HCl and reread at 410mμ and 430mμ. This method, described by Moss (1967a,b) enabled the determination of naturally occurring pheophytin a, thus decreasing the possibility of overestimating the chlorophyll a content. Results were expressed in mg chlorophyll a/meter^2 *Scirpus* stem.

Cell counts

After the subsample for chlorophyll determination was removed, the remaining portion of each of the samples was preserved with known amounts of Lugol's iodine solution and formalin. A subsample was then removed and stored for cell count determination. Before counting, each subsample was vigorously shaken and, if necessary, placed in a sonication cleaner for 1 minute to insure as nearly a homogeneous distribution as possible. Three drops (0.1ml) were then placed on a slide and covered with a 22 x 40mm coverslip. The number of fields counted depended upon the population density, but the number was always in multiples of 25 (25, 50, 75, 100, or 150 fields). The maximum number of fields counted on any slide was 150. An attempt was made to count at least 300 to 500 organisms per slide. Individual cells within a colony were counted; but only those cells lying within the field were counted. Living samples were periodically examined for the presence of green flagellates. However, at no time during the study were green flagellates seen. The counts were expressed as the number of cells/meter^2 *Scirpus* stem. The cell volume for each identified species found was determined from an average of 100 cells.

Permanent Diatom Slides

Permanent diatom slides were prepared from each sample for species identification, seasonal cycle studies, and cell volume determination. Equal amounts of concentrated sulfuric and concentrated nitric acids were added to a known volume of each of the samples (either 10mls or 25mls depending upon population size). The acid was then boiled, almost to dryness. After each subsample had cooled, distilled water was added and then changed every day for six days to remove the remaining acid. The slurry of cleaned and acid-free frustules was then made up to 15mls with distilled water. One ml of this diluted slurry was then carefully spread on a coverslip, drop by drop, to ensure a fairly uniform covering and then was heated to dryness. The coverslip was mounted with Permount mounting medium. For seasonal cycles, 100 frustules per slide were counted (Round, 1960). The cell volume for each of the major diatom species was estimated from an average of 100 cells.

Statistical Analysis of Sampling Methods

Two representative samples, each of 10 stems, were collected so that the methods used for chlorophyll a determination and cell counts could be subjected to an analysis of variance as outlined in Davies (1954), Eaton and Moss (1966) Happey (1970) and Hickman (1970, 1971.) The aim of the analysis was first to determine the total variation in each of the methods, and second, to determine the amount of variation introduced by the different stages in each of the methods with a hope of increasing the reliability of the methods within the limits created by available time and host *Scirpus* sp. population size.

In a general situation, let S samples be collected, F subsamples be prepared from each sample, and C counts be made on each subsample. Replicate counts differ only by the error introduced by counting so that the variance at the counting stage $= \sigma^2 c$ (1)

The variance of C replicate counts attributable to counting is $\sigma^2 c/_C$. The subsamples possess an additional source of variation which stems from variations between subsamples in addition to counting errors.

These two sources of error are independent of one another, and are additive, therefore, variance at the subsampling stage = $\sigma^2_f + \sigma^2_c/C$ (2). Similarly, the variance at the sampling stage would be $\sigma^2_s + \sigma^2_f/F + \sigma^2_c/CF$ (3).

The cumulative variances at each of the three stages are calculated first, and then the unknowns σ^2_s, σ^2_f, and σ^2_c are calculated from the above three simultaneous equations. The variance at the different stages and the cumulative variances for each of the methods has been expressed as the percentage deviation from the mean $100_{\sigma/\mu}$. This is synonymous with the coefficient of variation (C.V.).

Cell Counts

Ten sample stems were collected from each sample. Two subsamples of 25mls each were taken, and then from each subsample, two cell counts of 50 fields each were made.

The analysis of variance results are presented in Table 1 a, b, c, and d. Analyses were made for the total population and for the dominant species - *Spirogyra* sp., *Oedogonium* sp., and the total diatom population.

The analysis of the total population showed a high variance introduced by the sampling technique. Previous workers (Tippett 1969, Hickman 1971) have demonstrated the natural heterogeneity of the epiphytic community. The subsample preparation introduced very little variance, indicating that the shaking and ultrasonic treatment aided in homogenizing the sampled population. A high variance was introduced at the counting stage due to the presence of a heterogeneous algal population containing both filamentous and uni-

TABLE 1

Analysis of variance in the measurement of the standing crops of the epiphyton attached to *Scirpus validus* as measured by cell counts - (a) whole community, (b) *Spirogyra* sp., (c) *Oedogonium* sp., (d) Diatoms

(a) Whole Community

Source of Variation	σ^2	σ	Coefficient of Variation (% deviation from mean)
Sampling (S=10)	328	18.1	26.1
Sub-sampling (F=2)	8.5	2.9	4.2
Counting (C=2)	395	17.2	24.8
Whole Method	711	26.7	38.5

mean = 69.4 cells/unit area *Scirpus* stem

(b) *Spirogyra* sp.

Source of Variation	σ^2	σ	Coefficient of Variation (% deviation from mean)
Sampling (S=10)	51.0	7.1	29.8
Sub-sampling (F=2)	37.0	6.1	25.6
Counting (C=2)	71.0	8.4	35.3
Whole Method	150	12.2	51.3

mean = 23.8 cells/unit area *Scirpus* stem

(c) *Oedogonium* sp.

Source of Variation	σ^2	σ	Coefficient of Variation (% deviation from mean)
Sampling (S=10)	37.3	6.1	28.4
Sub-sampling (F=2)	8	2.9	13.5
Counting (C=2)	87	9.3	43.3
Whole Method	120	10.9	50.7

mean = 21.5 cells/unit area *Scirpus* stem

(d) Diatoms

Source of Variation	σ^2	σ	Coefficient of Variation (% deviation from mean)
Sampling (S=10)	2.46	1.56	11.0
Sub-sampling (F=2)	<0	0	0
Counting (C=2)	11.0	3.3	24.8
Whole Method	9.85	3.1	23.3

mean = 13.3 cells/unit area *Scirpus* stem cellular species.

The effects of filamentous species on method error was indicated with the results of the analysis of variance for *Spirogyra* sp. and *Oedogonium* sp. (Table 1(b)and(c)). The sampling error was similar to that of the whole community but the errors introduced by the other two stages in the procedure were much greater. This greater variance was due primarily to the lack of a homogeneous distribution of filamentous algae as compared to unicellular species. This difference is evident when the variance of these two filamentous species are compared to the variance of the combined diatom species (Table 1(d)). The chain forming diatoms that were present were broken up by the shaking and sonication processes thus creating a unicellular community of diatoms and reducing the natural heterogeneity. The negative variance calculated for the subsampling stage for the diatoms (Table 1(d)) may be taken to represent zero variance which again emphasized the more uniform dispersal of diatoms when compared to either *Oedogonium* sp. or *Spirogyra* sp.

The analysis of variance for the cell counting step showed that the major sources of variation were found in the sampling and counting stages. The error in the sampling method could be reduced by sampling more stems. However, the feasibility of increasing the sampling depended upon the time available and the need to conserve the sedge beds, especially when seasonal studies were undertaken. Both the time available and the relatively small size of the various sedge beds which were sampled dictated that no more than two stems per bed could be removed during any one sampling day. The large variation during the counting step could be reduced by counting more fields and thus more organisms. This was done as much as time permitted.

Chlorophyll a content determination

Ten sample stems were collected and from each of the 10 samples two subsamples were prepared. The chlorophyll a content was determined once for each subsample. Therefore, the variance at each stage is as follows:

the variance at the subsampling stage = σ^2_f (4)

the variance at the sampling stage = $\sigma^2_s + \sigma^2_f/F$. (5)

The analysis of variance for chlorophyll a content determination is presented in Table 2. As before the major source of variation was introduced at the sampling stage. The low error at the subsampling stage demonstrated the effectiveness of large subsamples which were filtered for chlorophyll analysis (10% to 25% of total sample) in removing a great amount of natural heterogeneity.

A decrease in the variation for this method could be obtained by taking more samples at each site. However, for the reasons listed above, this was impractical.

Conclusions

The analysis of variance for these two methods has supported the contentions of previous workers (Tippett 1969, Hickman 1971) concerning the natural heterogeneity of epiphytic populations. Although the variations determined for these two methods are quite high, they are comparable to those found by other workers for epiphytic communities (Tippett 1969, Hickman 1971). These variances are also below the

TABLE 2

Analysis of variance in the measurement of the standing crop of the epiphyton attached to *Scirpus validus* as measured by chlorophyll a content.

Source of Variation	σ^2	σ	Coefficient of Variation (% deviation from mean)
Sampling (S=10)	28.7	5.3	39.8
Sub-sampling (F=2)	1.11	1.05	7.9
Whole method	29.5	5.4	40.6

mean = 13.3 mg chlorophyll a/m^2 *Scirpus stem*

50% error suggested as adequate by Lund et al. (1958):

> "...Most experimental and ecological observations are concerned with generations, or changes in abundance of 100%. In such investigations then a method which can estimate abundance to ±50% is quite adequate and any time spent in making more accurate estimates is largely wasted."

Taxonomy

Diatoms were identified according to Hustedt (1930), Cleve-Euler (1951-55), and Patrick and Reimer (1968).

The green and blue-green algae were identified to species as often as possible according to Prescott (1962) and Bourrelly (1966, 1970).

During this study of the epiphyton, one hundred and forty species were identified and are listed in Table 3. The estimated volumes of the major algal species are presented in Table 4.

TABLE 3

Species Composition of the Epiphyton

Division Bacillariophyta

Achnanthes exigua Grun.

Achnanthes lanceolata (Bréb) Grun.

Achnanthes lanceolata (Bréb) Grun. var. *dubia* Grun.

Achnanthes minutissima Kütz

Achnanthes septentrionalis (Östr.)

Amphipleura pellucida Kütz.

Amphora ovalis Kütz.

Cocconeis pediculus Ehr.

Cocconeis placentula Ehr.

Cocconeis placentula Ehr. var *euglypta* (Ehr.) Cleve

Cyclotella comta (Ehr.) Kütz.

Cyclotella Meneghiniana Kütz.

Cymatopleura solea (Bréb.) W. Smith

Cymbella austriaca Grun.

Cymbella caespitosa (Kütz) Grun.

Cymbella cistula (Hemprich) Grun.

Cymbella cymbiformis (Agardh, Kütz.) v. Heurck

Cymbella heteropleura Ehr. Cleve

Cymbella hungarica (Grun.) Pant.

Cymbella lanceolata (Ehr.) v. Heurck

Cymbella microcephala Grun.

Cymbella parva (W. Smith) Cleve

Cymbella prostrata (Berkeley) Cleve

Table 3 (cont'd)

Cymbella prostrata (Berkeley) Cleve var. *robusta* A. Cleve

Cymbella ventricosa Kütz.

Diatoma anceps (Ehr.) Grun.

Diatoma elongatum Agardh.

Diatoma hiemale (Lyngb.) Heiberg.

Diatoma vulgare Bory

Epithemia argus Kütz.

Epithemia argus Kütz. var. *genuina* (Grun.) Mayer

Epithemia sorex Kütz.

Epithemia turgida (Ehr.) Kütz.

Epithemia zebra (Ehr.) Kütz.

Epithemia zebra (Ehr.) Kütz. var *genuina* Grun.

Epithemia zebra (Ehr.) Kütz. var. *porcellus* (Kütz.) Grun.

Eunotia diodon (Ehr.)

Eunotia sarekensis A. Bg.

Eunotia septentrionalis Ostr.

Fragilaria brevistriata Grun.

Fragilaria capucina Desmaz.

Fragilaria capucina Desmaz. var *mesoplepta* Rabh.

Fragilaria construens (Ehr.) Grun. var. *binodus* (Ehr.) Grun.

Fragilaria construens (Ehr.) Grun. var *construens* (Ehr.) Grun.

Fragilaria construens (Ehr.) Grun. var. *venter* (Ehr.) Grun.

Fragilaria leptostauron (Ehr.) Hust.

Fragilaria pinnata Ehr. var. *parallela* Mayer

Fragilaria vaucheriae (Kütz.) Pet.

Fragilaria vaucheriae (Kütz.) Pet. var *capitellata* (Grun.)

Fragilaria vaucheriae (Kütz.) Pet. var *genuina* (v. Heurck) A. Cleve

Table 3 (cont'd)

Gomphonema acuminatum (Ehr.)

Gomphonema acuminatum (Ehr.) var *elongatum* (W. Smith)

Gomphonema constrictum Ehr.

Gomphonema gracile Ehr.

Gomphonema gracile Ehr. var *genuinum* Mayer

Gomphonema intricatum Kütz.

Gomphonema longiceps Ehr. var *subclavata* Grun.

Gomphonema olivaceum (Lyngb.) Kütz.

Gomphonema olivaceum (Lyngb.) Kütz. var *calcarea* Cleve

Gomphonema parvulum Kütz.

Gomphonema sphaerophorum Ehr.

Gyrosigma acuminatum (Kütz.) Rabh.

Gyrosigma scalproides (Rabh.) Cleve

Hantzschia amphioxys (Ehr.) Grun.

Mastogloia elliptica Agardh. var *danseii* (Thwaites) Grun.

Mastogloia smithii Thwaites var *lacustris* Grun.

Melosira ambigua (Grun.) O. Müll.

Melosira granulata (Ehr.) Rolfs.

Melosira variens C.A. Ag.

Navicula amphibola Cleve

Navicula anglica Ralfs.

Navicula cryptocephala Kütz.

Navicula cuspidata Kütz.

Navicula elginensis (Greg.)

Navicula gastrum Ehr.

Navicula hungarica Grun. var *genuina* A. Cleve

(Table 3 cont'd)

Navicula pupula Kütz. var *rectangularis* (Greg.) Grun.

Navicula radiosa Kütz. var *minutissima* (Grun.) Cleve

Navicula radiosa Kütz. var *radiosa* Kütz.

Navicula radiosa Kütz. var *tennela* (Bréb.) Grun.

Navicula salinarum Grun.

Navicula scutelloides W. Smith

Navicula tripunctata (O.F. Müll.) Bory

Navicula viridula Kütz.

Navicula vulpina Kütz.

Nitzschia acicularis W. Smith

Nitzschia amphibia Grun.

Nitschia amphibia Grun. var *acutiuscula* Grun.

Nitzschia apiculata (Greg.) Grun.

Nitzschia dissipata (Kütz.) Grun.

Nitzschia fonticola Grun.

Nitzschia gracilis Hantzsch

Nitzschia ignorata Krasske

Nitzschia recta Hantzsch

Nitzschia romana Grun.

Nitzschia sigmoidea (Ehr.) W. Smith

Nitzschia sinuata (W. Smith) Grun var *tabellaria* Grun.

Nitzschia sublinearis Hust.

Opephora martyi Hérib.

Pinnularia cuneata (Östr.) A. Cleve var *reducta* A. Cleve

Pinnularia viridus (Nitzsch) Ehr.

Rhoicosphenia curvata Grun. var *curvata* (Kütz.) Grun.

Table 3 (cont'd)

Rhopalodia gibba (Ehr.) O. Müll.

Rhopalodia parallela (Grun.) O. Müll.

Stauroneis Smithii Grun.

Stephanodiscus astraea (Ehr.) Grun.

Surirella ovata Kütz.

Synedra acus Kütz.

Synedra pulchella Kütz.

Synedra pulchella Kütz. var *minuata* Hust.

Synedra rumpens Kütz.

Synedra ulna (Nitzsch) Ehr.

Tabellaria fenestrata (Lyngb.) Kütz.

Division Chlorophyta

Bulbochaete sp.

Coelastrum microporum Naegeli.

Cosmarium hammeri Reinsch.

Cosmarium protractum (Nag.) D. By.

Dictyosphaerium pulchellum Wood

Draparnaldia glomerata (Vauch.) C.A. Agardh

Mougeotia sp.

Oedogonium sp.

Oocystis sp.

Pandorina morum (Müll) Bory

Pediastrum Boryanum (Turp.) Meneghini

Rhizoclonium sp.

Scenedesmus quadricauda (Turp.) Bréb.

Spirogyra sp.

Table 3 (cont'd)

Stigeoclonium tenue (C.A. Agardh.) Kuetzing

Ulothrix sp.

Zygnema sp.

Division Cyanophyta

Anabaena sp.

Lyngbya sp.

Lyngbya limnetica Lemmermann

Merismopedia glauca (Ehr.) Nägeli

Microcystis aeruginosa (Kütz.)

Oscillatoria amoena (Kütz.) Gomont.

Oscillatoria rubescens De Candolle

Rivularia sp.

Tolypothrix sp.

TABLE 4

Estimated Volumes of Selected Algal Species
(based on measurements of 100 cell)

Division Bacillariophyta	
Achnanthes minutissima	50μ^3
Cocconeis placentula	800μ^3
Diatoma elongatum	300μ^3
Diatoma vulgare	3,400μ^3
Epithemia turgida	2,100μ^3
Fragilaria capucina	500μ^3
Fragilaria vaucheriae	520μ^3
Gomphonema gracile	260μ^3
Gomphonema olivaceum	540μ^3
Gomphonema parvulum	130μ^3
Melosira varians	8,000μ^3
Rhoicosphenia curvata v. *curvata*	180μ^3
Synedra acus	650μ^3
Synedra pulchella	900μ^3
Division Chlorophyta	
Oedogonium sp.	83,500μ^3
Spirogyra sp.	70,800μ^3
Mougeotia sp.	1,500μ^3
Draparnaldia glomerata	3,600μ^3
Division Cyanophyta	
Oscillatoria tenuis	110μ^3
Lyngbya limnetica	85μ^3

DESCRIPTION OF STUDY AREA

Lake Wabamun is located in central Alberta between latitudes 53° 30' and 53° 34' N and longitudes 114° 26' and 114° 44' W. The lake is situated approximately 65 kilometers west of Edmonton and 1.5 kilometers south of Highway 16.

Geology

The lake is situated in a low relief area of gently sloped hills and valleys very similar to the plains of central and eastern Alberta. The Wabamun Lake area is divided into two major drainage systems, the Pembina River System flowing north and ultimately draining into the Arctic Ocean, and the North Saskatchewan River System which flows eastward into Hudson Bay. Tnere is evidence that the lakes of this area, Lac St. Anne, Low Water Lake, Chip Lake, Isle Lake, and Wabamun Lake are merely remnants of a much larger lake which was probably formed by the melting ice from the last period of glaciation. After the break-up of this large lake but during periods of higher water than at present, it appears that Isle Lake and Wabamun Lake were united into one lake, due to the low relief of the land now dividing the two lakes. It is also speculated that during times of higher water levels, Lake Wabamun extended much farther east than its present shore and that the many small lakes south of Duffield, Alberta are remnants of this larger Lake Wabamun (Rutherford 1928).

The bedrock of the Wabamun area is primarily sandstone and shale originating from deposits in a freshwater lake system during the late Cretaceous and early Tertiary Ages. The uppermost Cretaceous beds belong to the Edmonton formation and are very rich in coal deposits, while the Tertiary beds belong to the Paskapoo formation (Rutherford 1928).

Climate

The meterological data for the months covering this study were obtained from the Stoney Plain Weather Station (53^0 33' N, 114^0 06' W, elevation 2512 feet) with the exception of the monthly total hours of sunlight, which was obtained from the weather station of the Edmonton Industrial Airport (53^0 30' N, 113^0 30' W, elevation 2200 feet). This data is summarized in Table 5.

The mean temperature (39.5^{0}C) for the duration of the study was very similar to the long term average (40.0^{0}C). The only two months that varied greatly from their corresponding monthly averages were December 1971 and February 1972. Both months were colder by 6^{0}F and 11^{0}F respectively, than their long term counterparts.

The mean total precipitation (2.18 in) for the study period was higher than the long term average (1.82 in). During the early summer (June and July) of 1971 the precipitation was nearly double that of the long term average. However, the month of August 1971 was much drier than normal. During 1972 the months of February, April, and June were wetter than normal while July was drier. These abnormalities in precipitation were generally not reflected in the total hours of sunlight per month.

During most of the 16-month study period, the prevailing winds were from a north-westerly direction. Only during the late winter of 1972 (February and March) were the winds from a south-easterly direction. Wheelock (1969) reported that the winds were generally strongest during the early afternoon and dying down towards sunset. This corresponds with my observations.

TABLE 5

Meteorological Summary From May 1971 to August 1972 with Long-term Averages

	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Mean
Mean Monthly Temperature - ^oF																	
71-72	54.9	56.2	59.8	64.1	48.5	40.4	24.4	3.0	0.6	3.8	25.0	36.7	53.4	58.9	58.0	63.3	39.5
Avg.	52.0	57.9	60.8	61.1	50.7	39.6	23.5	9.3	-0.7	15.0	22.6	37.3	52.0	57.9	60.8	61.1	40.0
Mean Monthly Precipitation - Inches																	
71-72	0.68	5.17	7.33	0.48	1.43	0.10	1.03	2.08	0.84	1.77	00.92	1.63	1.73	4.49	2.05	3.34	2.18
Avg.	1.07	3.27	3.56	2.75	1.34	0.96	0.92	1.16	1.15	0.67	0.84	0.68	1.07	3.27	3.56	2.75	1.82
Total Sunlight - Hours																	
71-72	308	215	304	317	161	176	76	83	81	76	150	240	302	269	258	316	
Avg.	272	265	306	269	185	161	105	80	91	113	176	224	272	265	306	269	
Mean Wing Speed - Miles per hour																	
71-72	7.6	7.5	7.3	6.1	7.0	7.0	7.7	7.0	7.4	5.4	5.7	9.1	6.9	7.8	6.8	5.8	7.1
Avg.	7.9	7.4	6.9	6.4	7.2	7.2	7.0	7.0	6.6	6.5	6.9	8.1	7.9	7.4	6.9	6.4	7.1
Wind Direction																	
71-72	NW	W	W	SE	NW	NW	NW	NW	NW	E	SE	NW	SE	NW	NW	NW	NW
Avg.	NW	NW	NW	NW	NW	NW	SW	NW	NW	W	E	SE	NW	NW	NW	NW	NW

LAKE WABAMUN

General Features

A morphometric map (Fig. 1) shows the depth contours drawn at 2 meter invervals. The morphometric parameters of the lake presented in Table 6 are from Nursall and Gallup (1971).

Inflow into the lake is primarily through precipitation on the lake surface, although there are several intermittent streams along the southern and western shores that flow into the lake. However, except for a brief period during spring runoff, these streams are dry. Nursall, Nuttall, and Fritz (1972) have suggested that subsurface inflow may be an important feature in the water cycle of the lake. They have presented evidence concerning the existance of a subsurface river flowing from Lake Isle into Lake Wabamun along a Pleistocene river channel. Water loss is through evaporation, surface, and subsurface outflow. Surface outflow is by way of Wabamun Creek which drains into the North Saskatchewan River. Subsurface outflow is thought to be in a southerly and southeasterly direction, again following the Pleistocene river channel.

Two electric generating plants have been constructed along the shores of Lake Wabamun, due primarily to the many coal seams that are found near the lake. Both power plants draw in lake water for cooling the condensers. This heated lake water is then discharged directly back into the lake. The location of these two power plants is shown in Figure 1.

Wabamun Sampling Stations

The Wabamun Power Plant, the older of the two plants, has a maximum production capacity of 600 megawatts. The plant draws its

FIGURE 1. Morphometric map of Lake Wabamun, showing the locations of the two power plants. Depth contours are drawn at 2 meter intervals.

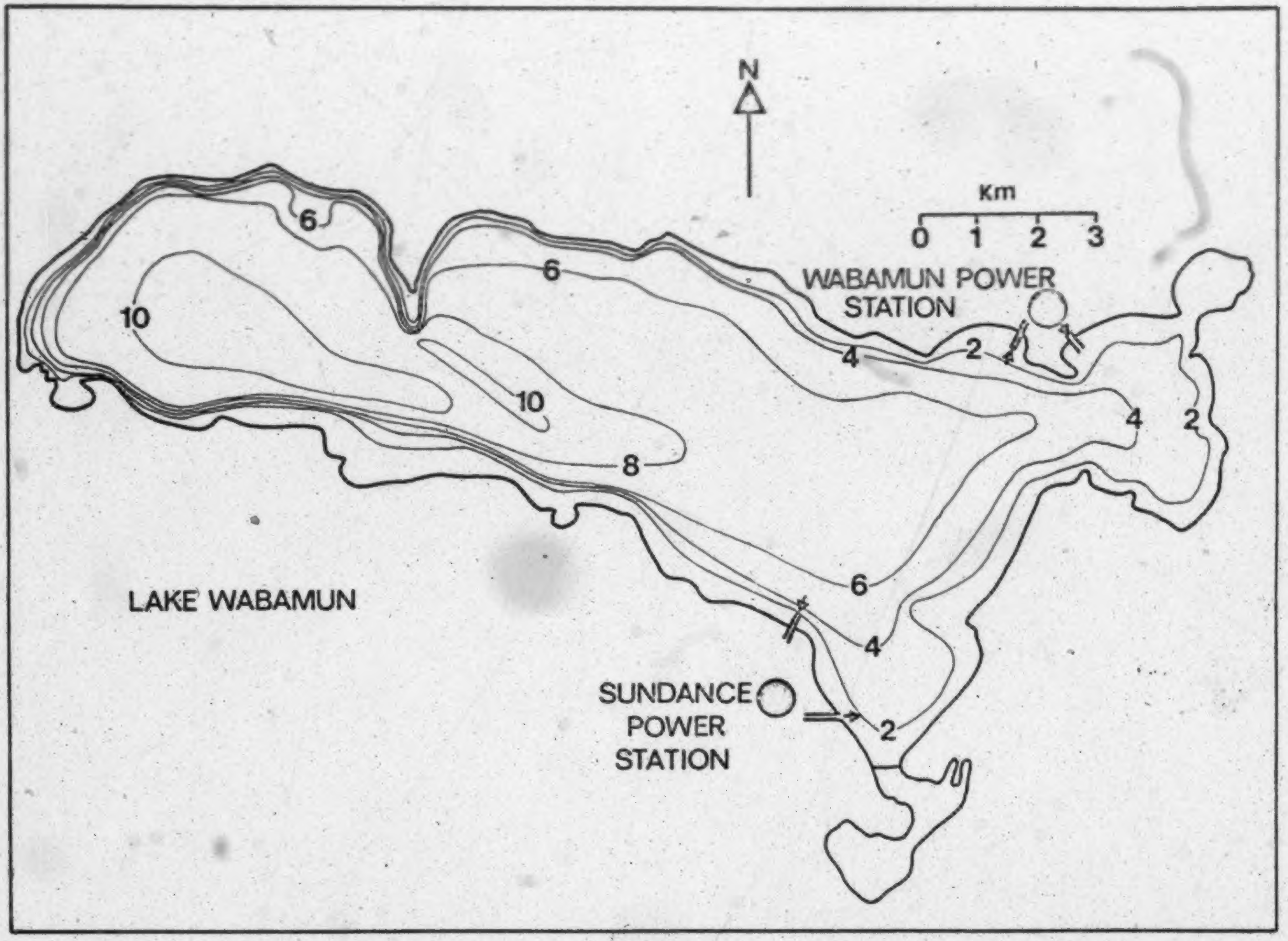

N
Km
0 1 2 3
WABAMUN POWER STATION
SUNDANCE POWER STATION
LAKE WABAMUN
2
4
6
8
10

TABLE 6

MORPHOMETRY - LAKE WABAMUN

Elevation	722.7	m
Area	82.5	Km^2
Volume	0.455	Km^3
Length	19.2	Km
Maximum breadth	6.6	Km
Mean breadth	4.3	Km
Maximum depth	11.6	m
Mean depth	5.4	m
Shoreline length	57.3	Km
Drainage basin	372.4	Km^2

cooling water from the western edge of a small promontory, Point Alison, while it discharges the heated water into a small sheltered part of Kapasiwin Bay, on the eastern side of Pt. Alison. During the warm water months (May to October) the plant draws in and discharges approximately 300,000 imperial gallons per minute. From October until late April, one of the two circulating pumps is shut down, so the water circulation rate is only one-half that of the summer water rate.

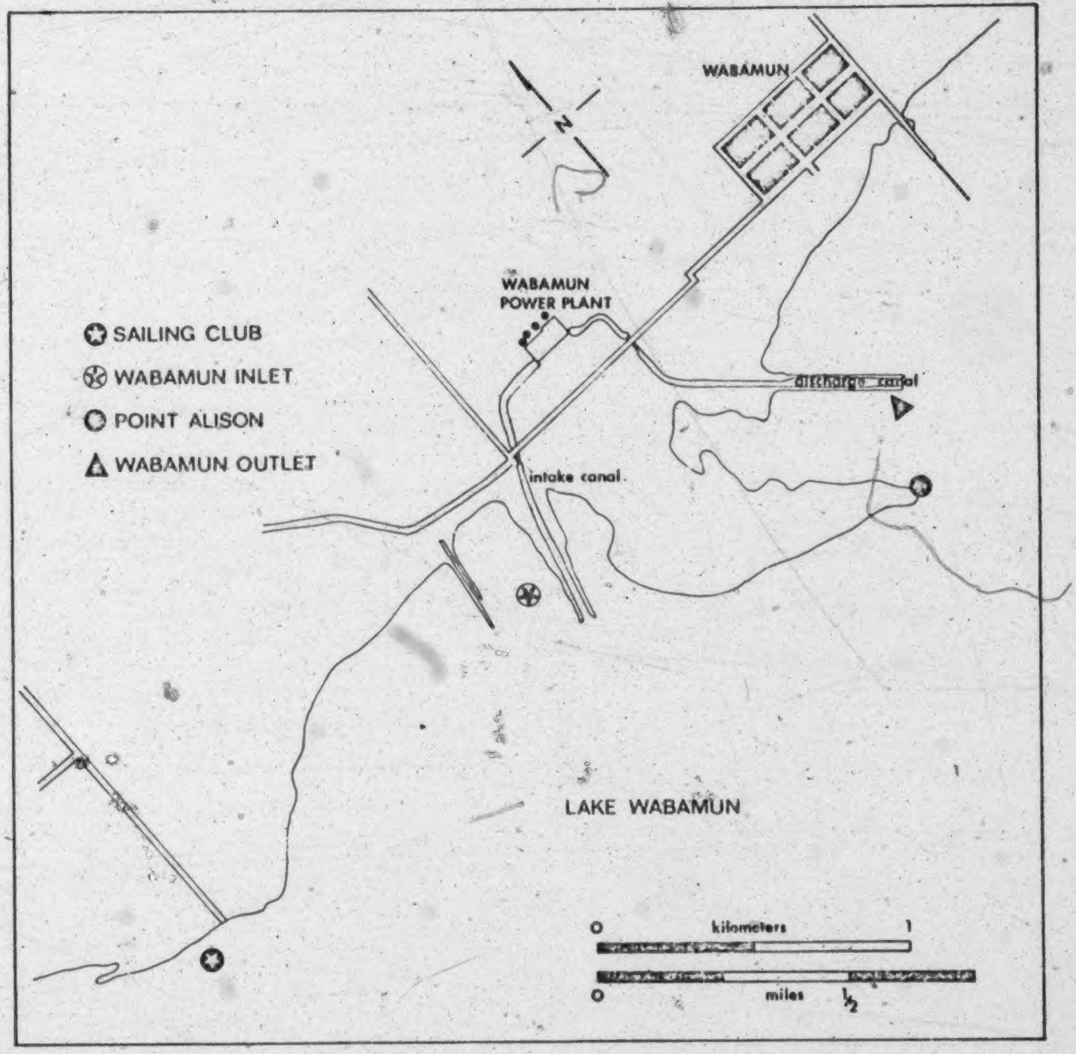
The shoreline in this study area, with the exception of two areas, just west of the intake canal and on both sides of the discharge canal, has been developed for recreational purposes with the construction of summer cottages and hamlets. This study area, with the exception of the complications introduced by the power plant, is fairly representative of the western, northern, and eastern shores of Lake Wabamun, all of which are areas of extensive lakeside development.

Four sampling stations were established in the Wabamun Power Plant area (Figure 2). Two control sites were established; Site SC was chosen as a site disturbed by boating activity, while site WI was relatively undisturbed. Both of the heated sites, PA and WO, were generally ignored by the boating public and thus were also relatively undisturbed.

Site Sailing Club (SC)

Site SC, the disturbed control site, was situated adjacent to the Wabamun Sailing Club in the proximity of several summer cottages (Figure 2). Due to the location of this site, man-made turbulence was always a potent environmental factor. During the first summer the original *Scirpus* sp. bed was destroyed by a cottage owner whose land bordered the bed. Following the destruction of this bed, the

FIGURE 2. Map of Wabamun Power Plant area showing location of sampling sites: Sailing Club (SC), Wabamun Inlet (WI), Point Alison (PA), and Wabamun Outlet (WO).


WABAMUN
N
WABAMUN POWER PLANT
SAILING CLUB
WABAMUN INLET
POINT ALISON
WABAMUN OUTLET
discharge canal
intake canal.
LAKE WABAMUN
0
kilometers
1
0
miles
½

sampling station was moved from its original location on the eastern perimeter of the Sailing Club to another small sedge bed on the western edge of the club. Although this area was rich in emergent vegetation, each individual *Scirpus* sp. bed was very small and sharply defined.

Physical

Through the open water months of the study period, this site generally exhibited isothermal conditions (Figure 3) due to the extreme shallowness - 0.75 meters - of this site. The maximum temperature, 23°C,was reached around mid-August during the two summers. The autumn cooling was a relatively slow process, beginning in early September and ending in early November when ice formed. Spring warming was a more rapid process; within the first two weeks after the ice had broken, the water temperature had risen to 10°C. By late May,summer water temperatures had been attained.

Turbidity reading ranged from 2 to 22 JTU with an average of 11 JTU (Table 1, Appendix A). Although there was no seasonal pattern evident in the turbidity readings, they appeared to be correlated with water agitation.

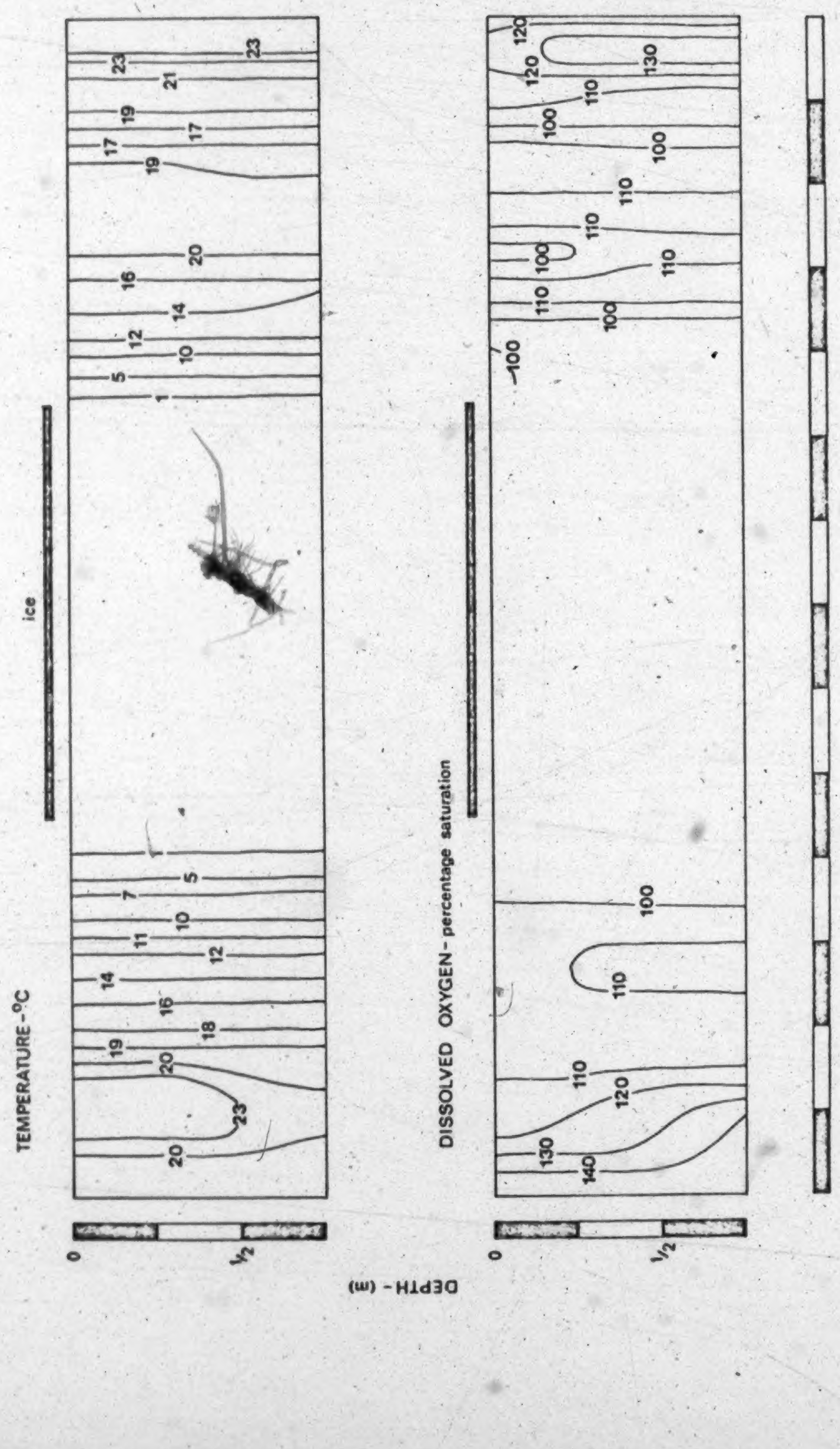
Chemical

Dissolved gases

Dissolved Oxygen - As with temperature, due to the shallowness of the site there was virtually no oxygen stratification (Figure 3). During the months this station was ice-free, the dissolved oxygen level was just above the 100% saturation level. The highest levels were attained during mid-summer (July, 1971 and August, 1972).

Free Carbon Dioxide - The concentrations of free carbon dioxide

FIGURE 3. Seasonal changes in water temperature and dissolved oxygen at site SC from July 1971 through August 1972. Isopleths of dissolved oxygen are expressed as percentage saturation. Period of ice cover is indicated.


TEMPERATURE - °C
ice
20
23
20
19
18
16
14
12
11
10
7
5
1
5
10
12
14
16
20
19
17
17
19
21
23
23
DISSOLVED OXYGEN - percentage saturation
140
130
120
110
110
100
100
100
110
100
110
110
110
110
100
100
110
120
130
120
120
DEPTH - (m)
0
½
0
½
J
A
S
O
N
D
J
F
M
A
M
J
J
A
1971
1972

ranged from 0.1 mg/l to 1.5 mg/l (Table 1, Appendix A).

Dissolved solutes (Table 1, Appendix A)

Hydrogen Ion Concentration - The hydrogen ion concentration (pH) varied from 8.40 to 9.44 with a mean of 8.82.

Alkalinity - Total alkalinity varied from 124.1 mg/l (26 mg/l carbonate alkalinity and 98.1 mg/l bicarbonate alkalinity) to 180.5 mg/L (33 mg/l carbonate and 147.5 mg/l bicarbonate). The mean total alkalinity was 157.4 mg/l (23 mg/l carbonate and 134.4 mg/l bicarbonate).

Hardness - Total hardness (EDTA) varied from 93 mg/l to 172 mg/l with a mean value of 121 mg/l.

Phosphate - Orthophosphate concentrations ranged from 0.002 mg/l to 0.03 mg/l. The mean was 0.012 mg/l. No seasonal cycle was observed.

Nitrate - Nitrate nitrogen was probably the most prevalent form of nitrogen present due to the high oxygen levels. Nitrate varied from 0.05 mg/l to 0.02 mg/l with an average of 0.03 mg/l. No seasonal trend was evident at this site.

Silica - The range of silica concentrations was from 1.5 mg/l to 8.4 mg/l with an average of 2.5 mg/l. No seasonal variation in silica was apparent at this station.

Iron - Ferrous iron concentrations varied from 0.02 mg/l to 0.12 mg/l. The mean value was 0.05 mg/l.

Sulphate- Sulphate concentrations were fairly constant, ranging from 18 mg/l to 40 mg/l. Except for the one high reading, all of the readings were between 18 mg/l and 32 mg/l. The mean was 26 mg/l.

Chloride - Chloride varied between 0.11 mg/l and 12 mg/l with an average of 2.3 mg/l.

Fluoride - Fluoride concentration was determined twice during the course of the study. In both instances, the concentration was below 0.5 mg/l.

Potassium - Potassium was present in such a minute quantity that it was undetectable.

Manganese - Manganese, as potassium, was determined twice during the study. The concentration in both cases was 0.04 mg/l.

Filterable Dissolved Solids - Filterable dissolved solids varied from 130.0 mg/l to 256.0 mg/l with a mean of 205.6 mg/l. No seasonal trend was evident.

Specific Conductance - Conductance readings were very similar through the course of the study, ranging from 280 to 390 micromhos with an average value of 345 micromhos.

Biotic

Shortly after ice break-up, the first macrophyte to appear was *Equisetum fluviatile*. These plants, however, rapidly disappeared as *Scirpus validus* began to appear.

Site Wabamun Inlet (WI)

Site WI, the undisturbed control site, was situated immediately westward of the inlet canal (Figure 2). This sedge bed, being bordered by land controlled by Calgary Power, was generally ignored by the boating public. Periodically fishermen would anchor and fish near the *Scirpus* bed, but none were seen to penetrate the bed. Sedge samples were taken about 5 meters in from the edge of the bed.

Physical

Isothermal conditions were usual due, as with Site SC, to the shallowness of the site (Figure 4). Only once during the study, mid-August, 1972, was there any stratification. Unlike SC, the cooling process during the autumn was not a relatively slow and constant process, but rather consisted of two periods of very rapid cooling, late August to mid-September, and mid-October to early November, separated by a period of stable temperatures.

Turbidity readings ranged from 1 to 21 JTU with an average of 10 JTU (Table 2, Appendix A).

Chemical

Dissolved gases

Dissolved Oxygen - As with SC, the dissolved oxygen values were around the saturation level, 90% to 120% saturation (Figure 4). Except for July, 1971, and mid-June, 1972, there was little oxygen stratification.

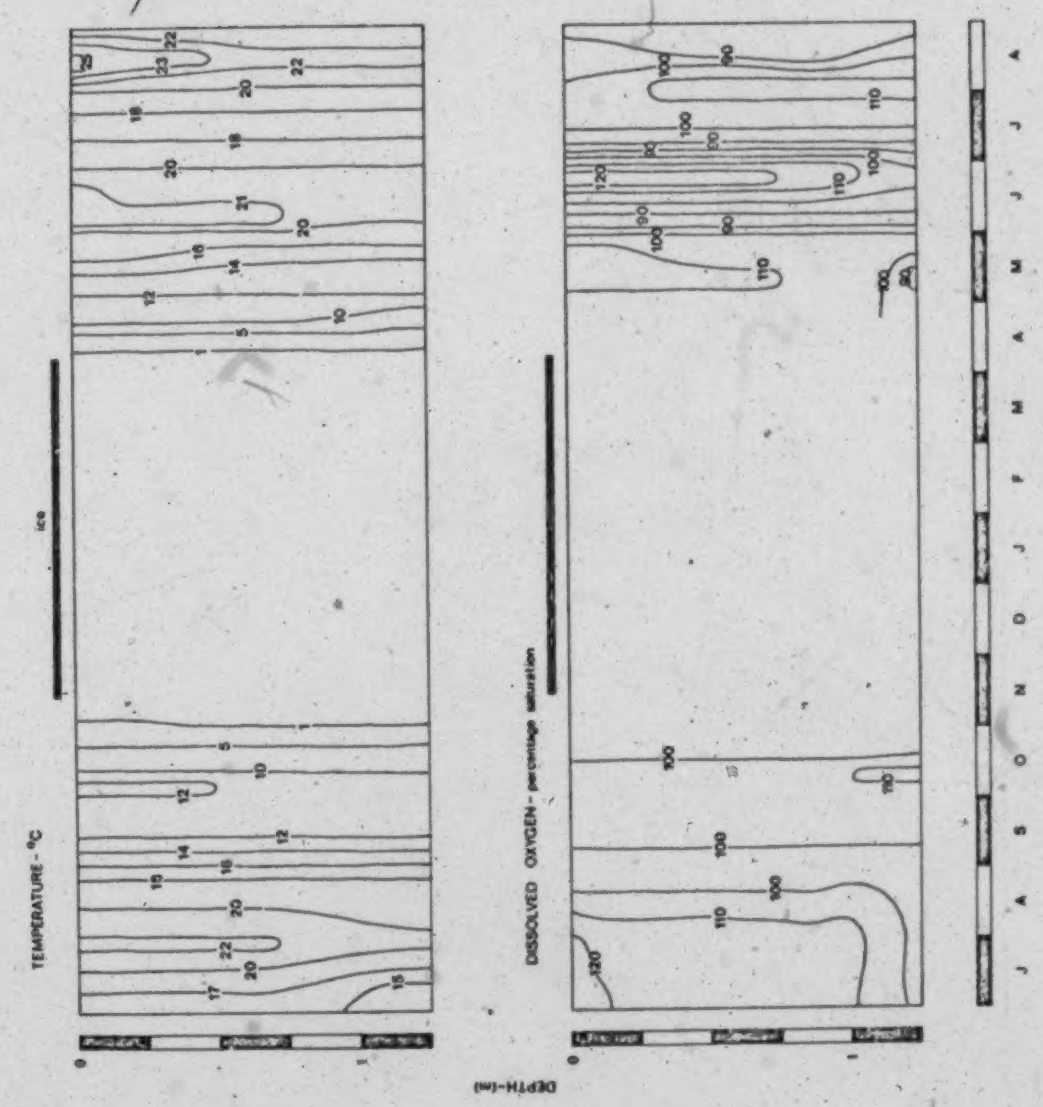
Free Carbon Dioxide - Free carbon dioxide concentrations ranged from less than 0.1 mg/l to 1.5 mg/l (Table 2, Appendix A).

Dissolved solutes (Table 2, Appendix A)

Hydrogen Ion Concentration - pH values varied from 8.47 to 9.72 with a mean value of 8.93.

Alkalinity - Total alkalinity values were generally similar, ranging from 127.6 mg/l (37 mg/l carbonate and 90.6 mg/l bicarbonate) to 186.5 mg/l (32 mg/l carbonate and 154.5 mg/l bicarbonate). The mean was 159 mg/l (22 mg/l carbonate and 137 mg/l bicarbonate). During 1971, there appeared to be a gradual increase in total alkalinity from late April until early September. Such a trend was

FIGURE 4. Seasonal changes in water temperatures and dissolved oxygen at site WI from July 1971 through August 1972. Isopleths of dissolved oxygen are expressed as percentage saturation. Period of ice cover is indicated.


TEMPERATURE - °C
Ice
DISSOLVED OXYGEN - percentage saturation
DEPTH-(m)
0
1
J
A
S
O
N
D
J
F
M
A
M
J
J
A
1971
1972

not evident during 1972.

Hardness - Total hardness (EDTA) varied from 96 mg/l to 148 mg/l with a mean value of 117 mg/l.

Phosphate - Orthophosphate concentrations ranged from 0.001 mg/l to 0.02 mg/l with a mean of 0.007 mg/l. No seasonal trend was observed.

Nitrate - Nitrate nitrogen levels were very constant, ranging from 0.02 mg/l to 0.04 mg/l with an average of 0.03 mg/l. No seasonal trend was observed.

Silica - The range of silica concentration was from 1.05 mg/l to 3.5 mg/l. The average concentration was 2.0 mg/l. No seasonal variation in silica was apparent.

Iron - Ferrous iron concentration varied from 0.02 mg/l to 0.14 mg/l with a mean of 0.06 mg/l.

Sulphate- With the exception of a single high sulphate concentration of 64 mg/l in late April, 1971, the concentration of this compound was very constant, ranging from 32 mg/l to 13 mg/l. The average concentration was 27 mg/l.

Chloride - Chloride values ranged from 0.35 mg/l to 5 mg/l with a mean value of 2.34 mg/l.

Fluoride - Fluoride concentration was determined 3 times in the autumn of 1971. The concentration in all three samples was below 0.5 mg/l.

Potassium - The potassium concentration was so minute that it was undetectable the two times a determination was attempted.

Manganese - Manganese concentration, also determined twice, was slightly below 0.04 mg/l.

Filterable Dissolved Solids - Filterable dissolved solid concentrations varied from 70.4 mg/l to 323 mg/l with an average value of 224.1 mg/l.

Specific Conductance - Conductance values were very similar ranging from 300 to 400 micromhos with a mean of 348 micromhos.

Biotic

This sedge bed, while being fairly large, was very open unlike the other three sites in the Wabamun area. Growing among the *Scirpus* sp. was *Nuphar variegatum* Engelm. Although *Scirpus* sp. appeared earlier in the spring and persisted until freeze-up, the *Nuphar* sp. was present through most of the growing season.

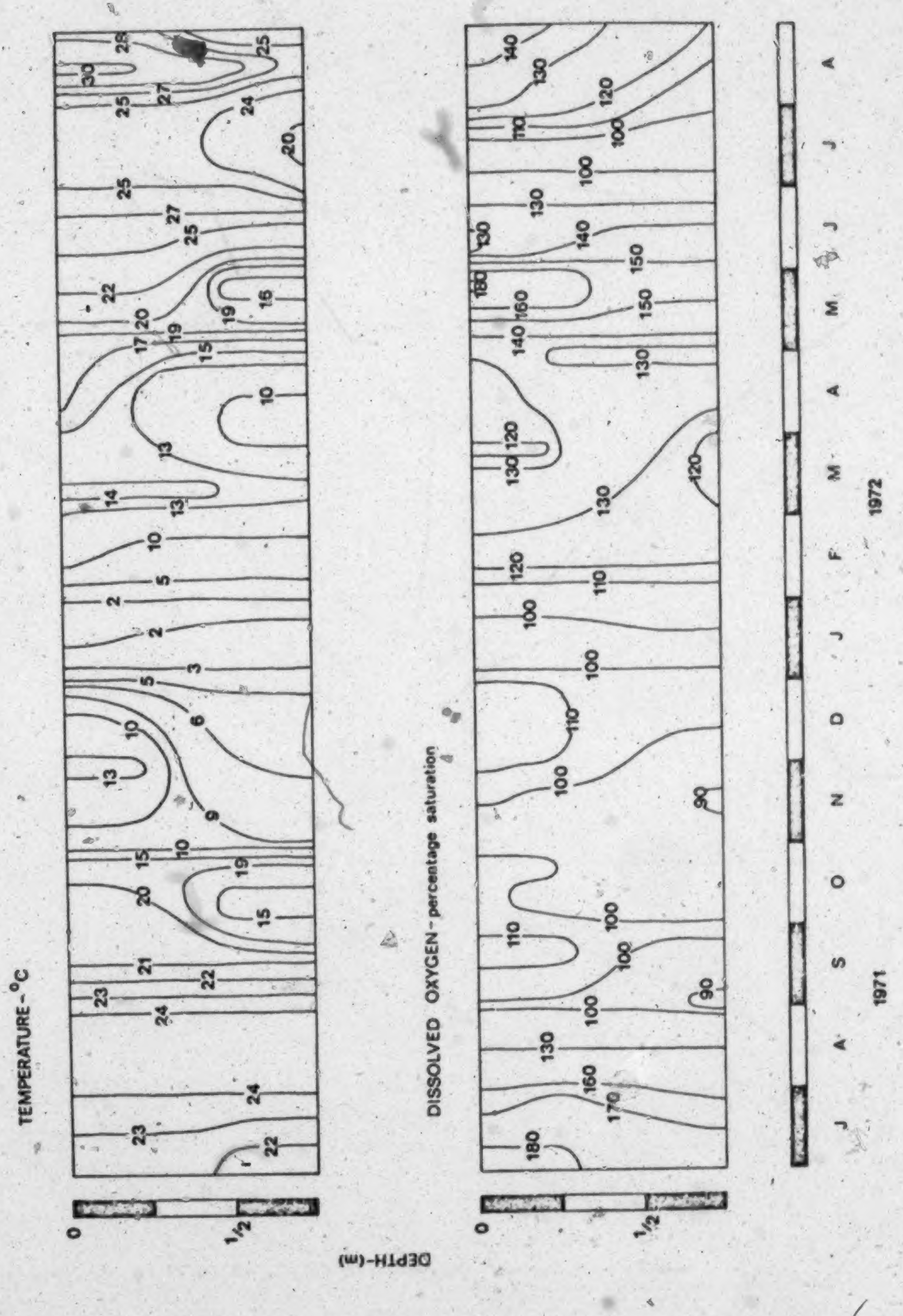
Site Point Alison (PA)

Site PA, located along the eastern shore of Point Alison and near the southern tip (Figure 2), was normally under the influence of the thermal discharge. This site, although bordering the property of a cottage owner, was generally undisturbed. The submerged macrophyte beds surrounding the site discouraged boaters and fishermen from approaching the site. This station was very sheltered as the point protected the site from most of the turbulence on the lake proper. The sampled *Scirpus* bed was very small and shallow, approximately 3/4 meters deep.

Physical

The influx of cooler lake water under the thermal discharge caused periodic thermal stratification at this site (Figure 5). As this site was on the periphery of the thermal plume, the station was prone to stratification caused by the inflow of ambient lake water under surface heated water or even the complete exclusion of heated

FIGURE 5. Seasonal changes in water temperature and dissolved oxygen at site PA from July 1971 through August 1972. Isopleths of dissolved oxygen are expressed as percentage saturation.


TEMPERATURE - °C
DISSOLVED OXYGEN - percentage saturation
DEPTH-(m)
0
1/2
0
1/2
J
A
S
O
N
D
J
F
M
A
M
J
J
A
1971
1972
23
22
24
23
24
21
22
20
15
19
15
10
13
10
9
6
5
3
2
2
5
10
13
14
13
10
15
17
20
19
19
16
22
25
27
25
25
20
24
25
27
30
28
25
180
160
170
130
100
90
110
100
100
100
110
100
100
120
110
130
130
120
120
140
130
160
180
130
150
150
140
130
100
110
100
120
130
140

water through changes in wind-generated circulation patterns. During the autumn and early spring, stratification was most prominent, although there was also stratification during the summer of 1972. Twice during the study, the thermal plume was virtually excluded from this site, during the late summer of 1971 and also during the month of January. The temperature changes caused by this exclusion during the summer were minimal, but the changes in the winter were both drastic and rapid. During late January, this station was briefly under a thin sheet of surface ice.

The turbidity reading fluctuated between 2 and 27 JTU over the study period with an average of 9 JTU (Table 3, Appendix A). With the exception of one value, the reading during the winter and early spring were slightly lower than those for the rest of the year.

Chemical

Dissolved gases

Dissolved Oxygen - The dissolved oxygen levels were usually at or well above 100% saturation (Figure 5). Stratification, although often present was not severe. The oxygen levels were higher during the spring and summer, reaching 180% saturation, than during the autumn and winter when the levels were very close to 100% saturation.

Free Carbon Dioxide - Free carbon dioxide levels varied from less than 0.1 mg/l to 1.7 mg/l (Table 3, Appendix A). No seasonally induced changes were evident.

Dissolved solutes (Table 3, Appendix A)

Hydrogen Ion Concentration - The pH ranged from 8.32 to 9.7 with an average of 8.99.

Alkalinity - Total alkalinity varied from 138.0 mg/l (24 mg/l carbonate and 114 mg/l bicarbonate) to 204.8 mg/l (42.2 mg/l carbonate and 162.6 mg/l bicarbonate) with a mean of 170.4 mg/l (30.6 mg/l carbonate and 139.8 mg/l bicarbonate). The alkalinity values, with one exception, were generally higher during the winter and early spring months than during the late spring, summer and autumn.

Hardness - Total hardness (EDTA) ranged from 88 mg/l to 200 mg/l with a mean of 124 mg/l.

Phosphate - Orthophosphate concentrations ranged from 0.001 mg/l to 0.09 mg/l with an average of 0.023 mg/l. Phosphate levels increased during the winter months and decreased during the spring. The level of phosphate in the water remained low through the summer.

Nitrate - Nitrate nitrogen varied from 0.02 mg/l to 0.06 mg/l with an average of 0.03 mg/l. During February and March, nitrate concentrations increased to a maximum of 0.06 mg/l by late March. The level of nitrate, however, quickly dropped to summer levels during April.

Silica - Silica levels ranged from 1.1 mg/l to 3.7 mg/l with a mean of 2.1 mg/l. The concentration of silica in the water increased during the autumn and winter until a maximum was attained in early February. The drop in silica corresponded with the drop in nitrate. Over the summer the silica level remained low until late summer when a rapid increase in silica caused a second maximum.

Iron - Ferrous iron varied from 0.03 mg/l to 0.10 mg/l with an average of 0.05 mg/l.

Sulphate- Sulphate concentrations varied little seasonally, ranging from 18 mg/l to 37 mg/l with a mean of 26 mg/l.

Chloride - Chloride varied from 0.71 mg/l to 11.0 mg/l with an average of 2.37 mg/l.

Fluoride - Fluoride concentrations were determined during the late summer and early autumn of 1971. The concentrations were always less than 0.05 mg/l.

Potassium - Potassium content in the water was undetectable the two times an analysis was made.

Manganese - Manganese values were under 0.04 mg/l when they were determined during the early summer, 1972.

Filterable Dissolved Solids - Filterable dissolved solids ranged from 67.6 mg/l up to 432.6 mg/l with an average of 230.8 mg/l.

Specific Conductance - Conductance values showed little variation, ranging from 310 to 420 micromhos with a mean of 361 micromhos.

Biotic

This site was surrounded by *Myriophyllum exalbescens* Fernald. and *Elodea canadensis* (Michx.) Planchon beds. The *Scirpus* sp.bed was very dense. As this site was virtually ice free, many of the *Scirpus* stems persisted through the winter until late May of the following year.

Site Wabamun Outlet (WO)

Site WO, a heated site, was located immediately west of the mouth of the discharge canal (Figure 2). This site was surrounded by beds of submerged macrophytes, which during the summer were so dense that movement through them was all but impossible. For this reason, the site was not sampled during the first summer from July to early October. During the summer of 1972, Calgary Power harvested many of these submerged macrophytes, thus sampling of the site was possible the second summer. This site was very shallow, approximately 3/4 meters deep.

Physical

The temperatures at this site were generally isothermal (Figure 6), although the periodic influx of cooler water into the bottom 0.25 meters caused some stratification. Even with this influx of cooler water, the temperature never dropped below 8^{0}C. The maximum temperature of 30^{0}C was attained by mid-August.

Turbidity values ranged from 2 JTU to 30 JTU with an average of 11.2 JTU. Of the four sites in the Wabamun area, this site had the largest range and the highest mean turbidity values. There was no seasonal trend evident.

Chemical

Dissolved gases

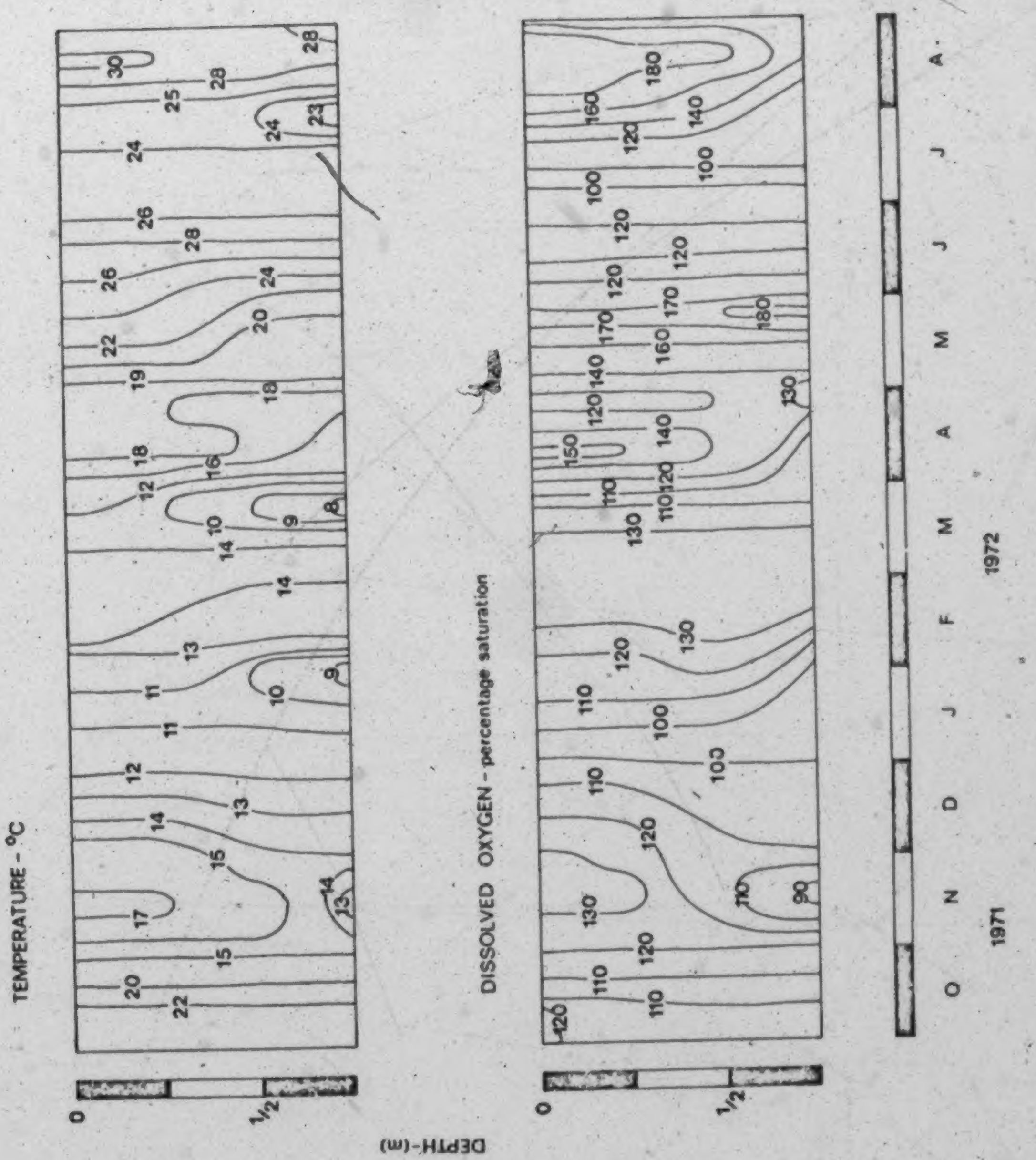
Dissolved Oxygen - The dissolved oxygen levels at this site were normally above 100% saturation (Figure 6). Only once during the study did the level drop to 90% saturation. A maximum level of 180% was reached during the late spring and mid-summer. As with site PA, the levels during the spring and summer were generally higher than during the autumn and winter.

Free Carbon Dioxide -Free carbon dioxide concentrations varied from less than 0.1 mg/l to 0.7 mg/l (Table 4, Appendix A). No seasonal trend was evident.

Dissolved solutes (Table 4, Appendix A)

Hydrogen Ion Concentration - The pH varied from 8.51 to 9.70 with an average of 8.97.

FIGURE 6. Seasonal changes in water temperature and dissolved oxygen at site WO from October 1971 through August 1972. Isopleths of dissolved oxygen are expressed as percentage saturation.



TEMPERATURE - °C

DISSOLVED OXYGEN - percentage saturation

Alkalinity - Total alkalinity varied from 128.0 mg/l (15.6 mg/l carbonate and 112.4 mg/l bicarbonate) to 197.5 mg/l (47 mg/l carbonate and 150.5 mg/l bicarbonate) with an average of 167.8 mg/l (31.4 mg/l carbonate and 136.4 mg/l bicarbonate). Alkalinity was generally higher during the winter and early spring (November to April) than during the late spring and summer.

Hardness - Total hardness (EDTA) ranged from 88 mg/l to 176 mg/l with an average value of 128 mg/l.

Phosphate - Orthophosphate levels varied from 0.002 mg/l to 0.24 mg/l with a mean of 0.034 mg/l. No seasonal trend was evident.

Nitrate - The nitrate concentration ranged from 0.02 mg/l to 0.06 mg/l with an average of 0.03 mg/l. During the late autumn and into the winter the nitrate concentration increased until late March, when the level dropped suddenly to summer levels.

Silica - Silica ranged from 1.5 mg/l up to 3.5 mg/l with a mean of 2.3 mg/l. During the autumn and winter silica increased until a maximum was attained. The sudden drop in silica levels corresponds with the drop in nitrate. A second maximum occurred in late August, 1972.

Iron - Iron varied from 0.02 mg/l to 0.08 mg/l with a mean of 0.05 mg/l.

Sulphate- Sulphate levels varied from 17 mg/l to 34 mg/l with an average of 25 mg/l.

Chloride - Chloride ranged from 0.11 mg/l to 8.77 mg/l with an average value of 2.48 mg/l.

Fluoride - Fluoride was determined once at this study site. The concentration during mid-October was less than 0.5 mg/l.

Potassium - Potassium analysis was attempted three times during the study. Each time the level of potassium was undetectable.

Manganese - Manganese levels were determined twice. The concentration both times was 0.014 mg/l.

Filterable Dissolved Solids - Filterable dissolved solids varied from 140.0 mg/l up to 393.8 mg/l with an average of 243.6 mg/l.

Specific Conductance - Conductance readings varied from 270 to 420 micromhos with an average of 356 micromhos. There was no seasonal variation observed.

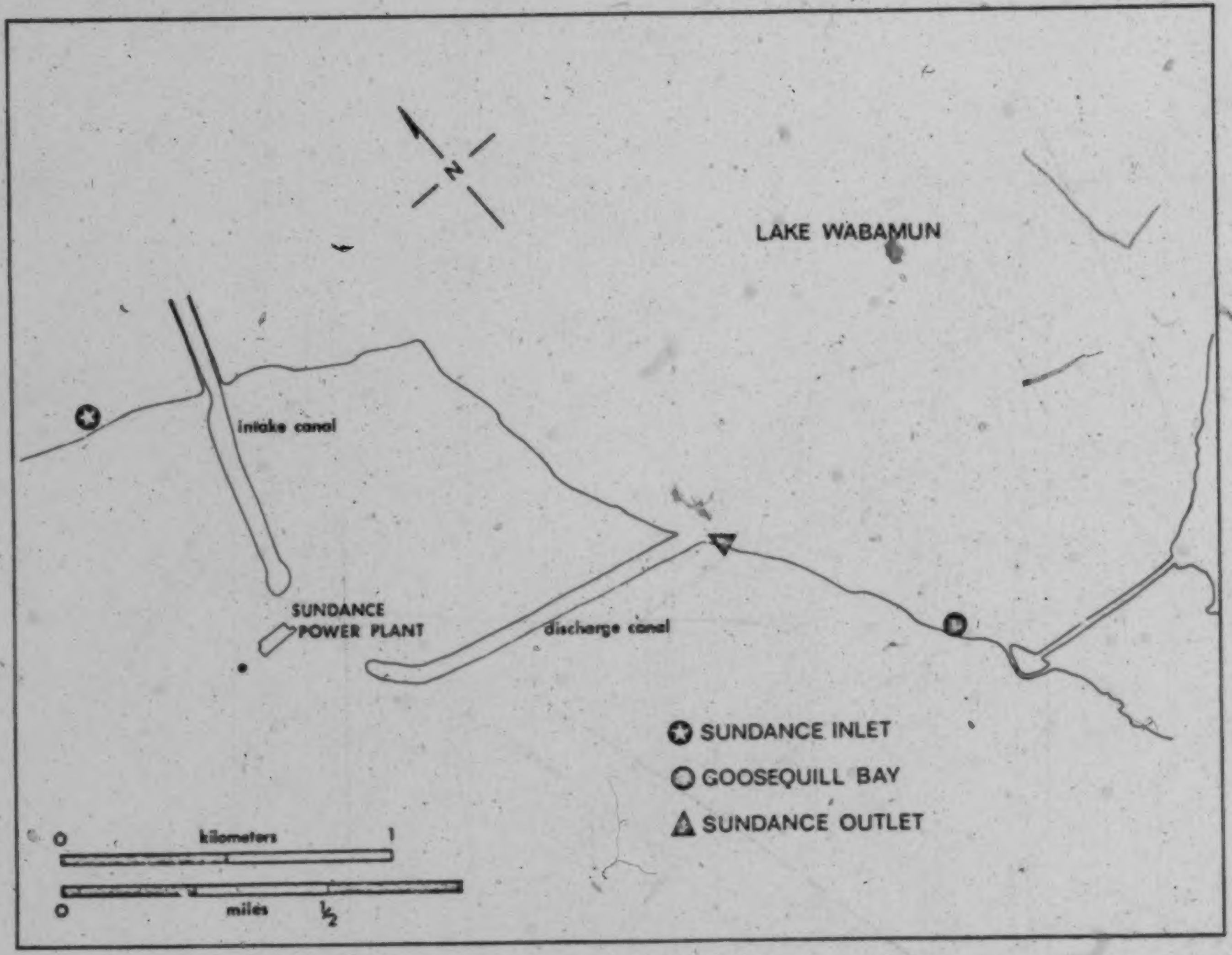
Biotic

This *Scirpus* sp.bed was immediately adjacent to beds of *Potamogeton pectinatus* L. Further out from the sedge bed were large beds of *Elodea canadensis*. The sampled sedge bed was very dense, thus trapping much floating debris, particularily floating macrophytes. Because of this entrapment, it was necessary to clear away the surface debris before collecting the samples during the summer.

Sundance Sampling Stations

The Sundance Power Station (Figure 1) became operational during the winter of 1970-71. Therefore, this study period encompassed many of the biotic transitional stages that accompanied the introduction of heated water into Goosequill Bay. This power station has a production capacity of 300 megawatts. The plant draws its cooling water from the southern shore of the lake proper, west of Goosequill Bay (Figure 7). The heated water is discharged into the southwestern section of Goosequill Bay. During the warm water months (April to October) the plant circulates 150,000 imperial gallons per minute for cooling the condensors, while the

FIGURE 7. Map of Sundance Power Plant area showing location of sampling sites: Sundance Inlet (SI), Goosequill Bay (GB), and Sundance Outlet (SO).


N
LAKE WABAMUN
intake canal
SUNDANCE
POWER PLANT
discharge canal
SUNDANCE INLET
GOOSEQUILL BAY
SUNDANCE OUTLET
0
kilometers
1
0
miles
½

winter rate is approximately one-half that amount.

Unlike the Wabamun study area, the shoreline in this study area is still undeveloped. The shoreline in this area is under control of either the Paul Band Indian Reserve or Calgary Power Ltd. This area of the lake was seldom used by the boating or fishing public so the degree of direct human disturbance on the sampling sites was negligible.

Three sampling stations were established in the Sundance Power Plant area (Figure 7). The control site SI was located on the lake proper while both the heated site SO and the semi-heated site GB were situated along the southern shore of Goosequill Bay.

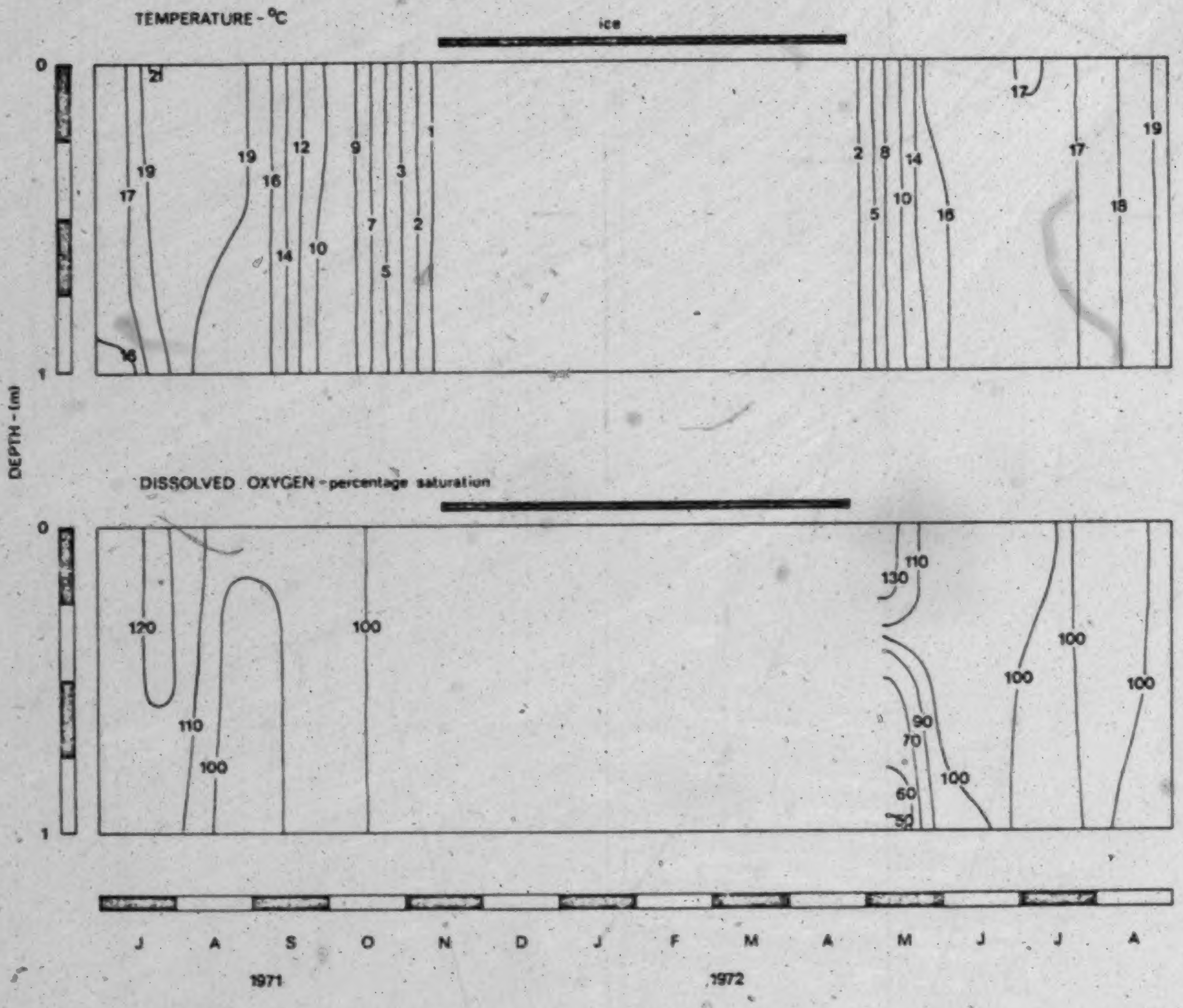
Site Sundance Inlet (SI)

Site SI (Figure 7), the control site, was located immediately west of the intake canal along the southern shore of the lake proper. Due to this exposed location, the site experienced more wind-generated water turbulence than the two sites situated in Goosequill Bay. The sedge samples were collected approximately 5 meters in from the edge of the bed where the water was about 1 meter deep.

Physical

During the study period there was no thermal stratification evident at this site (Figure 8). Autumn cooling was generally a continuous process from early September until freeze-up in mid-November. This cooling process was bisected by a two week period of stable temperatures during early October. The spring heating process was very rapid as summer temperatures were reached within a month of ice break-up.

FIGURE 8. Seasonal changes in water temperature and dissolved oxygen at site SI from July 1971 through August 1972. Isopleths of dissolved oxygen are expressed as percentage saturation. Period of ice cover is indicated.


TEMPERATURE - °C
ice
DEPTH - (m)
0
1
21
19
17
16
19
16
14
12
10
9
7
5
3
2
1
2
5
8
10
14
16
17
17
18
19
DISSOLVED OXYGEN - percentage saturation
120
110
100
100
130
110
90
70
60
50
100
100
100
100
J
A
S
O
N
D
J
F
M
A
M
J
J
A
1971
1972

Turbidity (Table 5, Appendix A) ranged from 4 to 18 JTU with a mean of 9 JTU. Although no definite trend was evident, it appeared that the turbidity was slightly higher during the spring and early summer than during the autumn.

Chemical

Dissolved gases

Dissolved Oxygen - There was no stratification at this site except for a brief period during May when the water column was undergoing rapid heating (Figure 8). Except for this period of stratification when the oxygen levels ranged from 130% at the surface to 50% at the bottom, the saturation levels were around 100%. The low oxygen levels in the deeper waters after ice break-up suggested that the oxygen levels in the water under the ice and near the sediment may have been low.

Free Carbon Dioxide - Free carbon dioxide varied from 0.2 mg/1 up to 1.8 mg/1. No seasonal trend was observed.

Dissolved solutes (Table 5, Appendix A)

Hydrogen Ion Concentration - The pH at this site ranged from 8.37 to 9.27 with an average of 8.88.

Alkalinity - Total alkalinity varied from 146.0 mg/1 (38.2 mg/1 carbonate and 107.8 mg/1 bicarbonate) to 178.9 mg/1 (33.4 mg/1 carbonate and 145.5 mg/1 bicarbonate) with a mean of 165.0 mg/1 (22.2 mg/1 carbonate and 142.8 mg/1 bicarbonate). Total alkalinity values were very consistant through the study.

Hardness - Total hardness (EDTA) ranged from 90 mg/1 to 138 mg/1 with a mean of 124 mg/1.

Phosphate - Orthophosphate concentrations varied from 0.002 mg/1 to 0.024 mg/l with a mean of 0.005 mg/l. No seasonal trend was evident.

Nitrate - Nitrate nitrogen varied from 0.01 mg/l to 0.05 mg/l with an average of 0.03 mg/l. No seasonal variation was noticed.

Silica - Silica ranged from 1.2 mg/l up to 3.2 mg/l with a mean of 1.9 mg/l. There was no seasonal pattern evident.

Iron - Ferrous iron varied from 0.02 mg/l to 0.06 mg/l with a mean of 0.05 mg/l.

Sulphate- There was little variation in sulphate concentrations. Sulphate ranged from 17 mg/l to 32 mg/l with an average of 26 mg/l.

Chloride - Chloride levels ranged from 0.95 mg/l to 2.48 mg/l. The average concentration was 1.58 mg/l.

Fluoride - The fluoride concentration in the water was determined once during the study. The level was below 0.5 mg/l.

Potassium - The potassium concentration was undetectable the two times an analysis was undertaken.

Manganese - The two manganese concentrations determined in the early summer of 1972 were 0.025 and 0.050 mg/l respectively. The average value was below 0.040 mg/l.

Filterable Dissolved Solids - Filterable dissolved solids ranged from 75.8 mg/l to 308.4 mg/l with an average of 224.9 mg/l.

Specific Conductance - Conductance values showed little variation, ranging from 290 to 380 micromhos with a mean of 345 micromhos.

Biotic

Like site WI, the sampled sedge bed at SI was large but very open. There were no other aquatic macrophytes growing among the

Scirpus stems. At the lakeward edge of the sedge bed, however, there were small open beds of *Potamogeton natans* L.

Site Goosequill Bay (GB)

Site GB was located close to the southern tip of Goosequill Bay (Figure 7). This site was very near the channel that connects the two portions of the original Goosequill Bay that was separated by the construction of a railroad causeway. The area now referred to as Goosequill Bay is that area of the original bay north of the causeway; the isolated southern portion has no name. The sampled site averaged 1.25 meters in depth.

Physical

This station had no thermal stratification except for a brief period during early July 1971 (Figure 9). The autumn cooling consisted of two periods (early to mid-September and mid- to late October) of rapid cooling separated by nearly a month (mid-September to mid-October) of constant temperatures. The ice at this site broke in late March, nearly a month ahead of the non-heated sites. Spring heating was a long (early April to late May) and deliberate process, perhaps due to this early ice break-up. The thermal effluent caused a slight increase in summer water temperatures of from 1° to 2°C. The shut-down of the Sundance Power Plant in late June and July caused a slight temperature reduction during mid-July.

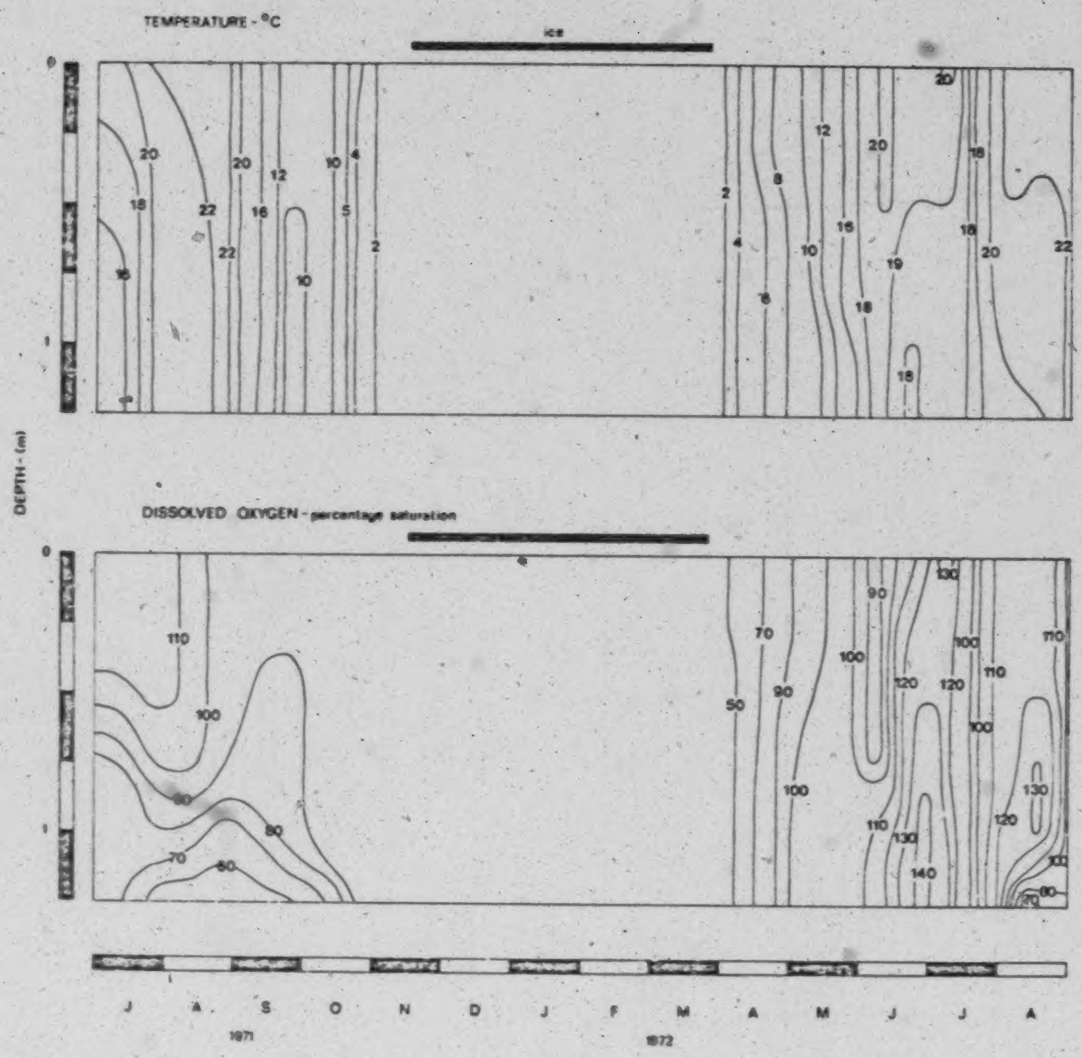
Turbidity ranged from 4 to 22 JTU with a mean of 11 JTU (Table 6, Appendix A). There was no seasonal trend observed.

Chemistry

Dissolved gases

Dissolved Oxygen - Unlike the other stations, this site showed

FIGURE 9. Seasonal changes in water temperature and dissolved oxygen at site GB from July 1971 through August 1972. Isopleths of dissolved oxygen are expressed as percentage saturation. Period of ice cover is indicated.


TEMPERATURE - °C
ice
DISSOLVED OXYGEN - percentage saturation
DEPTH - (m)
0
1
J
A
S
O
N
D
J
F
M
A
M
J
J
A
1971
1972
20
18
16
22
12
10
4
5
2
8
19
110
100
90
80
70
60
50
120
130
140

stratification through much of the study period (Figure 9). The late summer and early autumn period was characterized by stratification with the surface waters being slightly above 100% saturation and the bottom waters well below. There was some evidence towards the end of the second summer that this stratification is a yearly phenomenon. Periodically through the late spring and early summer there was moderate inverse stratification. The early and mid-spring months were characterized by increasing orthograde oxygen saturation levels beginning at 50% saturation. There was also an oxygen stratification during mid-summer, 1972. Although this time span corresponds with the shutdown of the Sundance Power Plant, there is no evidence to suggest that these two events were more than coincidental.

Free Carbon Dioxide - Free carbon dioxide ranged from 0.2 mg/L to 1.0 mg/L (Table 6, Appendix A). The levels of free carbon dioxide appeared to correspond with changes in pH.

Dissolved Solutes (Table 6, Appendix A)

Hydrogen Ion Concentration - The pH varied from 8.55 to 9.27 with an average of 8.89. The pH decreased during the autumn until freeze-up. After the ice broke, the pH remained low until mid-July when it rose to reach a maximum during the months of August and September.

Alkalinity - Total alkalinity ranged from 95.1 mg/l (3.2 mg/l carbonate and 91.9 mg/l bicarbonate) to 173.8 mg/l (32.8 mg/l carbonate and 141 mg/l bicarbonate). The mean was 151.8 mg/l (37.6 mg/l carbonate and 114.2 mg/l bicarbonate).

Hardness - Total hardness (EDTA) ranged from 92 mg/l to 140 mg/l with an average of 113 mg/l.

Phosphate - Orthophosphate concentrations varied from 0.002 mg/l to 0.21 mg/l with a mean of 0.025 mg/l. No seasonal trend could be established due to the inability of the original method to detect phosphate concentrations lower than 0.05 mg/l.

Nitrate - Nitrate levels ranged from 0.02 mg/l to 0.006 mg/l with an average of 0.04 mg/l. Nitrate levels increased during the autumn until freeze-up. After the ice broke, the level remained high until late spring - early summer when it rapidly dropped to a summer minimum.

Silica - Silica ranged from 0.6 mg/l to 2.8 mg/l with a mean of 1.9 mg/l. Silica levels remained high from late July until freeze-up. After break-up, the level remained high until early May when the level dropped to a summer minimum. The level remained low until late July. The sudden decrease in silica occurred two weeks earlier than the decrease in nitrate.

Iron - Ferrous iron concentrations, ranging from 0.02 mg/l to 0.10 mg/l with a mean of 0.06 mg/l, also showed some seasonal variation. Iron levels were generally higher during the autumn and early spring. The decrease to the summer minimum was a gradual process while the increase back to autumn levels appeared to be more abrupt.

Sulphate- Sulphate varied from 16 mg/l to 38 mg/l with a mean of 29 mg/l.

Chloride - Chloride ranged from 0.35 mg/l to 6.31 mg/l with an average of 1.89 mg/l.

Fluoride - Fluoride levels were determined three times during the autumn of 1971. Each time the level was below 0.5 mg/l.

Potassium - Potassium determination was attempted three times during the summer of 1972. In each case, the potassium concentration was undetectable.

Manganese - Manganese levels, like potassium, were determined three times during the summer of 1972. The average of the three readings was 0.036 mg/l.

Filterable Dissolved Solids - Filterable dissolved solids varied from 152.9 mg/l to 329.1 mg/l with an average of 225.5 mg/l.

Specific Conductance - Conductance levels varied from 290 to 390 micromhos with a mean of 339 micromhos.

Biotic

Although this site was not as open as SI, there were several other aquatic macrophytes associated with the *Scirpus* stems. During late spring of the first year, *Equisetum fluviatile* was growing among the *Scirpus* stems. With the advent of summer the *Equisetum* disappeared, never to be seen again during the study - even during the late spring of the second year. *Nuphar variegatum* was growing among the *Scirpus* through most of the two summers encompassed by the study. Outside the sedge bed, there were large beds of *Potamogeton Richardsonii* (Benn.) Rydb.

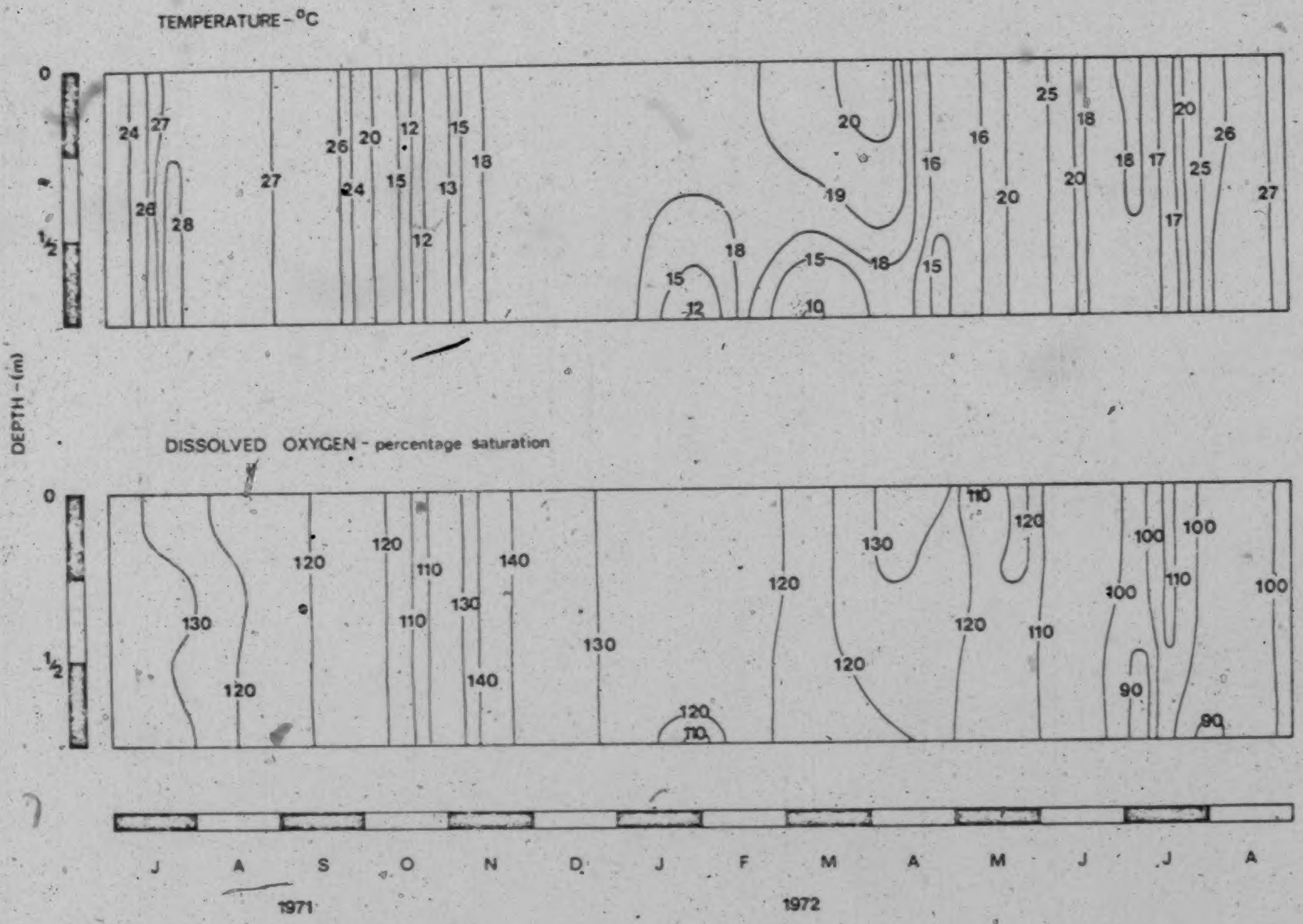
Site Sundance Outlet (SO)

Site SO was located immediately south of the mouth of the discharge canal (Figure 7). This site was surrounded by dense beds of submerged macrophytes.

Physical

This station was generally isothermal except for some stratification during February and March caused by an influx of cooler water in the lower 0.25 meter (Figure 10). Both autumn cooling

FIGURE 10. Seasonal changes in water temperature and dissolved oxygen at site SO from July 1971 through August 1972. Isopleths of dissolved oxygen are expressed as percentage saturation.



TEMPERATURE - °C

DISSOLVED OXYGEN - percentage saturation and spring heating of the water column were rapid processes. The temperature decrease in both October and April was caused respectively by the shutdown and then restarting of the second circulating pump. As mentioned previously, the Sundance Power Plant was closed down for repairs from mid-June to mid-July. This shutdown was shown by a decrease in temperatures at this site.

Turbidity ranged from 1 to 26 JTU with an average of 19 JTU (Table 7, Appendix A). No seasonal variation was evident.

Chemical

Dissolved gasses

Dissolved Oxygen - The oxygen levels at this site never reached the high saturation levels that were characteristic of the heated sites in the Wabamun area (Figure 10). The levels here never dropped below 90% saturation and rarely below 100% saturation. During the summer of 1971 the oxygen levels at the mouth of the canal reached a maximum of 130% saturation while during the summer of 1972 levels were around 100% saturation. The highest oxygen levels were attained during late autumn and early winter. There was virtually no oxygen stratification at this site.

Free Carbon Dioxide - Free carbon dioxide varied from less than 0.1 mg/l up to 1.1 mg/l (Table 7, Appendix A). There was no seasonal trend.

Dissolved solutes (Table 7, Appendix A)

Hydrogen Ion Concentration - The pH varied from 8.51 to 9.27 with an average of 8.95. There was no seasonal variation observed.

Alkalinity - Total alkalinity varied from 140.1 mg/l (22 mg/l carbonate and 118.1 mg/l bicarbonate) to 196.5 mg/l (44.4 mg/l carbonate and 152.1 mg/ bicarbonate) with an average of 167.9 mg/ (28.6 mg/ carbonate and 139.3 mg/ bicarbonate). Total alkalinity was generally higher during the winter months than during the summer months.

Hardness - Total hardness (EDTA) ranged from 45 mg/l to 152 mg/l with an average of 116 mg/l.

Phosphate - Orthophosphate concentrations ranged from 0.001 mg/l to 0.18 mg/l with an average of 0.033 mg/l. It appears that phosphate levels were higher during the winter than during the summer.

Nitrate - Nitrate nitrogen ranged from 0.01 mg/l to 0.09 mg/l with a mean of 0.04 mg/l. During the late winter (February to April) the nitrate concentrations increased to reach a maximum in late March. During late April, however, this high level quickly dropped to the low summer levels.

Silica - Silica concentrations varied from 1.03 mg/l to 3.4 mg/l with an average of 2.1 mg/l. Silica values generally increased over the winter to reach a maximum by late March. The level of silica quickly dropped to a spring minimum and remained at this low level until August when a second maximum occurred. The spring decline occurred approximately two weeks before the decline in nitrate.

Iron - Ferrous iron varied from 0.04 mg/l to 0.10 mg/l with an average concentration of 0.06 mg/l.

Sulphate - Sulphate ranged from 16 mg/l to 37 mg/l with a mean of 26 mg/l.

Chloride - Chloride concentrations varied from 0.71 mg/l to 8.00 mg/l with a mean of 2.30 mg/l.

Fluoride - Fluoride concentrations were determined twice during the study. In both cases, the concentration was under 0.5 mg/l.

Potassium - Potassium levels were determined three times during the study. Each time, the potassium concentration was undetectable.

Manganese - Manganese levels in the water were determined three times during the summer of 1972. The average level was 0.046 mg/l.

Filterable Dissolved Solids - Filterable dissolved solids ranged from 101.6 mg/l to 369.6 mg/l with an average of 241.9 mg/l. There was no seasonal trend observed.

Specific Conductance - Conductance values varied from 280 to 400 micromhos. The mean was 354 micromhos.

Biotic

This sedge bed was immediately adjacent to dense beds of *Elodea canadensis* which made approach from the lake side extremely difficult. Like site WO, this sedge bed was very dense, which caused the entrapment of much floating debris during the summer months.

SUMMARY

The seven sampling sites had similar physical and chemical regimes with the exception of temperature and dissolved oxygen. The dissolved oxygen saturation levels were generally higher at the heated sites than at the non-heated sites due to the extensive submerged macrophyte beds surrounding the former.

RESULTS

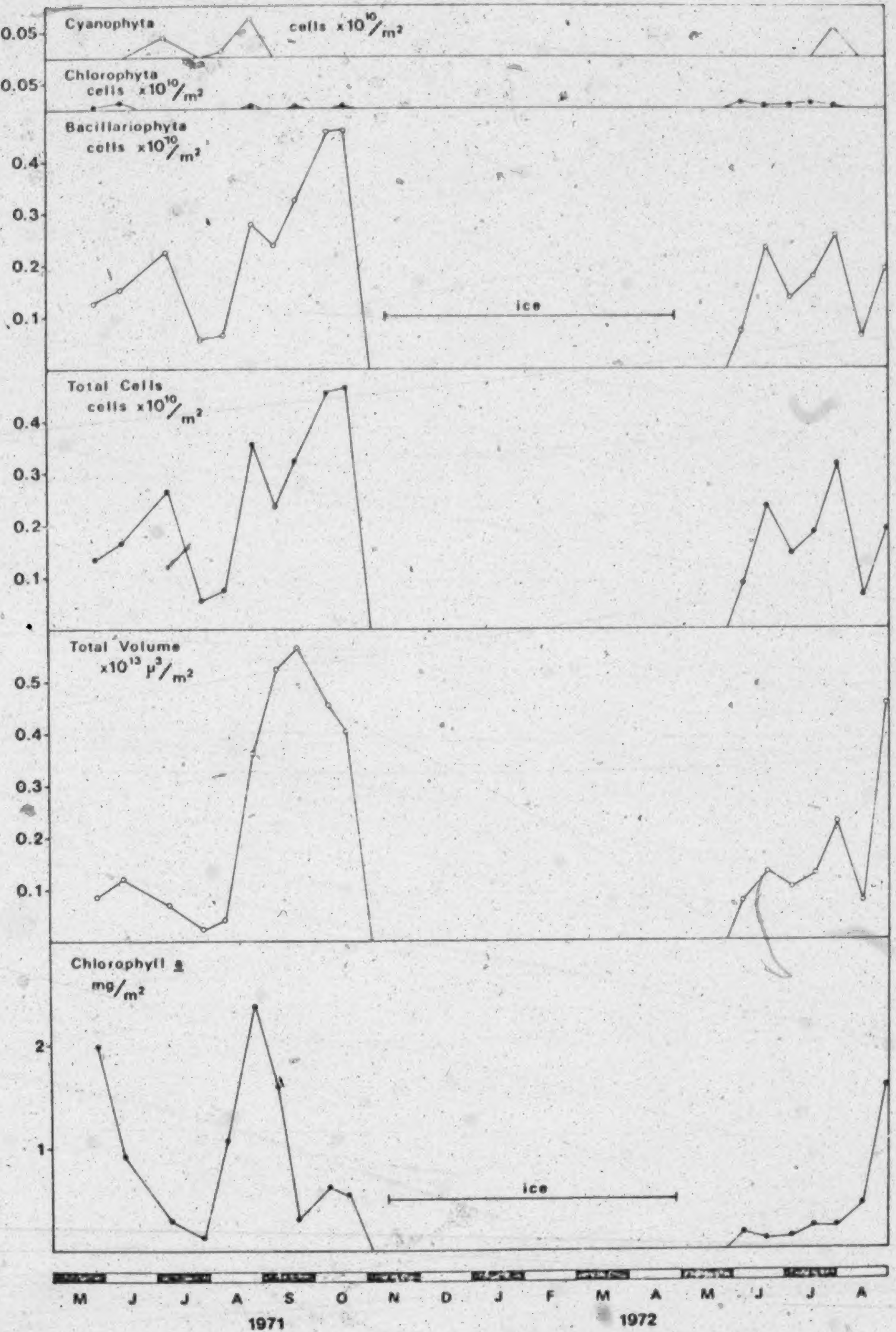
I Standing Crop and Seasonal Succession

Site Sailing Club (SC)

The epiphytic algal community at site SC was composed almost exclusively of diatoms. Most of the members of the Cyanophyta and Chlorophyta that were recorded were planktonic in origin, namely *Anabaena* sp., *Scenedesmus quadricauda* and *Pediastrum boryanum.*

The chlorophyll a content reached a small peak during late May, 1971, although the other two standing crop parameters showed no peak (Figure 11). The flora at this time was dominated by *Diatoma elongatum* (5.5 x 10^8 cells/m^2 host stem, 43% of the total population), although both *Fragilaria capucina* (1.6 x 10^8 cells/m^2 host stem) and *Synedra acus* (0.8 x 10^8 cells/m^2 host stem) were common. By early June both *Diatoma elongatum* and *Fragilaria capucina* had disappeared while *Synedra acus* had declined to 50% of its previous population. During June, as the chlorophyll a content showed a decrease; the total cell numbers showed an increase, together with total cell volume, to reach an early summer peak. *Achnanthes minutissima* (2.4 x 10^8 cells/m^2 host stem), *Fragilaria construens* var. *venter* (1.5 x 10^8 cells/m^2 host stem), *Gomphonema gracile* (3.3 x 10^8 cells/m^2 host stem), and particularly *Gomphonema parvulum* (6.7 x 10^8 cells/m^2 host stem) were responsible for the increase in total cell number during June. By early July a peak was reached in total cell numbers while the other two standing crop parameters showed a decline in population size. This peak in total cell numbers was dominated by *Gomphonema gracile* (6.7 x 10^8 cells/m^2 host stems) as the other three species began to decrease in numbers. During July *Gomphonema gracile* declined

FIGURE 11. Standing crop of the epiphyton at site SC expressed as per m^2 *Scirpus* sp. stem from May 1971 through August 1972. Period of ice cover is indicated.


Cyanophyta
cells x10^10/m²
0.05
Chlorophyta
cells x10^10/m²
0.05
Bacillariophyta
cells x10^10/m²
0.4
0.3
0.2
0.1
ice
Total Cells
cells x10^10/m²
0.4
0.3
0.2
0.1
Total Volume
x10^13 µ³/m²
0.5
0.4
0.3
0.2
0.1
Chlorophyll a
mg/m²
2
1
ice
M
J
J
A
S
O
N
D
J
F
M
A
M
J
J
A
1971
1972

in cell numbers. There was first an increase in species diversity as no species assumed dominance, but then in late July *Cocconeis placentula* rapidly became the most common species as the water temperature increased. By early August when a summer maximum in water temperature ($23^{o}C$) was attained, *Cocconeis placentula* with 6 x 10^8 cells/m^2 host stem accounted for 52% of the total population. During July all three standing crop parameters showed a minimum. However, during August all three showed an increase in the standing crop; chlorophyll a content in early August, and total cell numbers and total cell volume in mid-August. During late August the decreasing water temperature corresponded to a decline in the importance of *Cocconeis placentula*. *C. placentula* remained a common species until just prior to ice formation, when there was an increase in *Achnanthes minutissima* and *Gomphonema gracile* populations. *Epithemia turgida* was first recorded in the population in late August and by late September had reached a peak of 2.2 x 10^8 cells/m^2 host stem. From late August until ice formation in early November, *Achnanthes minutissima* was the dominant species. The peak in *Epithemia turgida*, a large-celled alga, was primarily responsible for the autumn maximum in total cell volume during late September, a month after the autumn peak in chlorophyll a content and a month before the peak in total cell numbers. *Mougeotia* sp., a filamentous member of the Chlorophyta, was briefly recorded in the population during late September, but in very small numbers. During October, *Achnanthes minutissima* continued to increase in population size until a maximum of 2.3 x 10^9 cells/m^2 host stem was recorded in late October. This coincided with the previously mentioned autumn peak in total cell numbers. Other common algae during October included

, *Gomphonema parvulum*, *Synedra acus*, and *Cocconeis placentula*. By early November, the *Scirpus* sp. stems had disappeared. Ice formation occurred; therefore, sampling was suspended for the winter.

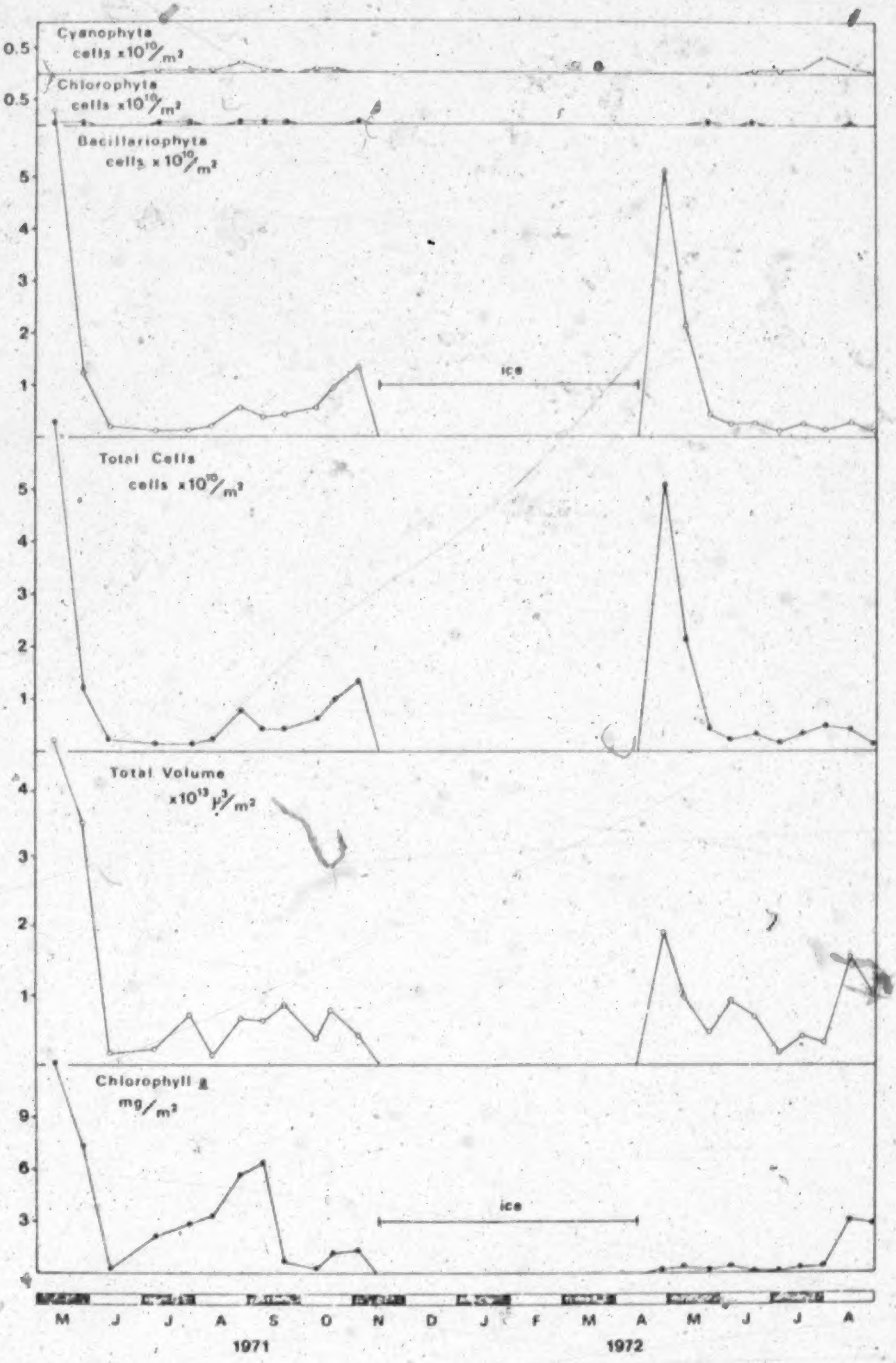
In 1972, *Scirpus* sp. did not appear until early June, a month later than in 1971. Perhaps this was partially responsible for the lack of a spring maximum in any of the standing crop parameters. *Diatoma elongatum* was again the dominant species, although it appeared as though this diatom population was declining by the time the first sample was taken since *Gomphonema parvulum* and *Achnanthes minutissima*, and *Fragilaria construens* var. *venter* together, accounted for over 25% of the total population. Also *Fragilaria capucina* the other spring dominant, was less than 5% of the total population. By mid-June, *Diatoma elongatum* had declined to less than 3% of the total population. At this time *Gomphonema gracile* was the most common species with 7.8×10^8 cells/m^2 host stem, while *Gomphonema parvulum*, *Gomphonema intricatum* and *Fragilaria vaucheriae* were also common. During July, *Cocconeis placentula* increased in numbers until it was a major component of the population, accounting for 15 to 20% of the population (3.4×10^8 cells/m^2 host stem), although *Gomphonema gracile* with 6.4×10^8 cells/m^2 host stem remained the dominant species. By early August *Cocconeis placentula* had, as in 1971, assumed dominance, but by mid-August a decline in the population of *Cocconeis placentula* resulted in three species becoming dominant, *Achnanthes minutissima* (8×10^7 cells/m^2 host stem), *Cocconeis placentula* (9×10^7 cells/m^2 host stem), and *Gomphonema gracile* (14×10^7 cells/m^2 host stem). By the end of August *Cocconeis placentula* and *Gomphonema gracile* had both increased in population size (6.4 x 10^8 cells and 4.5 x 10^8 cells/m^2 host stem, respecively) to share dominance while *Achnanthes minutissima* declined in importance as it showed a very small increase in population size (8 x 10^7 to 9 x 10^7 cells/m^2 host stem) during the same period. Unlike 1971, *Epithemia turgida* was recorded during the entire summer, but never became a common species until late August.

Site Wabamun Inlet (WI)

During 1971 all three standing crop parameters showed a major spring peak at this site on May 11 (Figure 12). This large standing crop rapidly declined to a summer minimum which occurred by early June. The length of this summer minimum varied with each of the standing crop parameters; total cell numbers remained low for two months, while chlorophyll a content began to rise immediately, and cell volume recorded an intermediate summer minimum period. Chlorophyll a content showed a continuous, but irregular increase until a peak was reached in early September which was followed by a rapid decrease. A small peak occurred during late October and early November just before ice formation. Cell volumes showed minor peaks during late July, late September, and late October, but there was no distinct autumn maximum. The standing crop, as measured by total cell numbers, showed a small peak during late August and then a large peak in early November.

The spring maximum was dominated by *Diatoma elongatum*, which with 3.8 x 10^{10} cells/m^2 host stem accounted for 60% of the total population. *Fragilaria construens* var. *venter* (3.8 x 10^{10} cells/m^2 host stem), *Surirella ovata* (3.1 x 10^{10} cells/m^2 host stem), and *Synedra acus* (2.5 x 10^9 cells/m^2 host stem) were common but none were

FIGURE 12. Standing crop of the epiphyton at site WI expressed as per m^2 *Scirpus* stem from May 1971 through August 1972. Period of ice cover is indicated.


Cyanophyta
cells x10^10/m²
0.5
Chlorophyta
cells x10^10/m²
0.5
Bacillariophyta
cells x10^10/m²
5
4
3
2
1
ice
Total Cells
cells x10^10/m²
5
4
3
2
1
Total Volume
x10^13 µ³/m²
4
3
2
1
Chlorophyll a
mg/m²
9
6
3
ice
M
J
J
A
S
O
N
D
J
F
M
A
M
J
J
A
1971
1972

more than 6% of the total population. By late May, although there had been a rapid decline in the population of *Diatoma elongatum* (3.8 x 10^{10} cells/m^2 host stem on May 11 to 0.4 x 10^{10} cells/m^2 host stem on May 27), it still remained the dominant alga, accounting for 43% of the total population. During this decline in the population size of *Diatoma elongatum*, there was an increase in the populations of *Fragilaria vaucheriae* (.9 to 2 x 10^9 cells/m^2 host stem) and *Fragilaria brevistrata* (1.2 x 10^9 to 1.3 x 10^9 cells/m^2 host stem). *Epithemia turgida*, *Gomphonema parvulum*, *Synedra acus*, and *Oedogonium* sp. were also common at this time. By early June a standing crop minimum occurred. This was caused by the disappearance of *Diatoma elongatum*, *Fragilaria vaucheriae*, and *Synedra acus* and also a great decrease in the numbers of *Fragilaria brevistrata*. In early June, *Cocconeis placentula* and *Gomphonema parvulum* along with *Gomphonema gracile* were the most common species accounting for 12%, 20% and 26% of the total population, respectively. *Gomphonema gracile* was the only species that showed a rapid increase in cell numbers at this time as both the *Cocconeis placentula* and *Gomphonema parvulum* populations changed very little from their late May levels.

During July total cell numbers continued to decline slightly, but both total cell volume and chlorophyll a content increased. This was probably due to an increase in the population size of the large-celled *Epithemia turgida* and *Epithemia sorex* along with *Achnanthes minutissima* which assumed dominance in early July. At this time, the populations of *Gomphonema gracile* and *Gomphonema parvulum* had declined while that of *Cocconeis placentula* changed only slightly. The *Achnanthes minutissima* population declined in late July (3.6 x

10^9 cells/m^2 host stem) while the two *Epithemia* species continued to show an increase in numbers, 7.5 x 10^8 to 29 x 10^8 cells/m^2 host stem for *Epithemia turgida* and 2.5 x 10^8 to 13 x 10^8 cells/m^2 host stem for *Epithemia sorex*. However in early August the populations of *Epithemia turgida* and *E. sorex* declined rapidly. This decline was shown by total cell volume but not by total cell counts or chlorophyll a content as they both showed an increase in standing crop at this time. The increase in total numbers was due to a rapid increase in the population of *Achnanthes minutissima* (1.5 x 10^8 to 11.0 to 10^8 cells/m^2 host stem) and to smaller increases *Gomphonema gracile* and *Gomphonema parvulum*. At this time *Achnanthes minutissima* accounted for 55% of the total population while *Cocconeis placentula* and *Gomphonema gracile* each comprised 12% of the total population. During August the numbers of *Gomphonema gracile* increased rapidly while those of *Achnanthes minutissima* increased only slightly until by August 26 they each represented 38% of the total population with 2.2 x 10^9 cells/m^2 host stem respectively. *Cocconeis placentula* was still common at this time accounting for 9% of the total population. During September *Diatoma elongatum* reappeared although it was never a major component of the epiphyton during the autumn. *Achnanthes minutissima* and *Gomphonema gracile* remained the most common species through September, together accounting for 55 to 60% of the total population. *Cocconeis placentula* and *Epithemia turgida* were also common, although *C. placentula* decreased from 4.9 x 10^8 cells/m^2 host stem to 2.5 x 10^8 cells/m^2 host stem while *E. turgida* increased from 2.3 x 10^8 cells to 3.4 x 10^8 cells/m^2 host stem. In early September *Mougeotia* sp. briefly appeared but not in large numbers.

During October and early November, *Achnanthes minutissima* became the dominant species, increasing in numbers from 1 x 10^9 cells/m^2 host stem in late September to 10 x 10^9 cells/m^2 host stem in early November and from 44% to 77% of the total population. Through this period of decreasing water temperatures and decreasing day length, the other common species declined in numbers with the exception of *Gomphonema gracile* which showed an increase from 3 x 10^8 cells/m^2 host stem to 15 x 10^8 cells/m^2 host stem. Just prior to ice formation in mid-November, *Stigeoclonium tenue* was briefly recorded in the epiphyton.

During 1972, the spring standing crop maximum was shown in total cell numbers but not in chlorophyll a content while total cell volume was intermediate, showing only a slight increase. This could have been caused by a dominance of *Fragilaria capucina* during 1972 which has a much smaller chloroplast area per unit cell volume than *Diatoma elongatum* which was the only dominant during the spring maximum in 1971. The standing crop as measured by total cell numbers was smaller in 1972 (5.1 x 10^{10} cells/m^2 host stem) than in 1971 (6.3 x 10^{10} cells/m^2 host stem). During May, as the total population was declining, *Diatoma elongatum* first shared dominance with *Fragilaria capucina* and then became the sole dominant by the end of the month as its population was declining slower than that of *Fragilaria capucina.* In early June the most common algae were *Achnanthes minutissima* (4.4 x 10^8 cells/m^2 host stem), *Diatoma elongatum* (3.9 x 10^8 cells/m^2 host stem), and *Epithemia turgida* (3.9 x 10^8 cells/m^2 host stem). During this time *Gomphonema gracile* was undergoing a period of rapid growth. By the end of the month *Gomphonema gracile* shared dominance with *Achnanthes minutissima* and by early July *Gomphonema gracile* was the

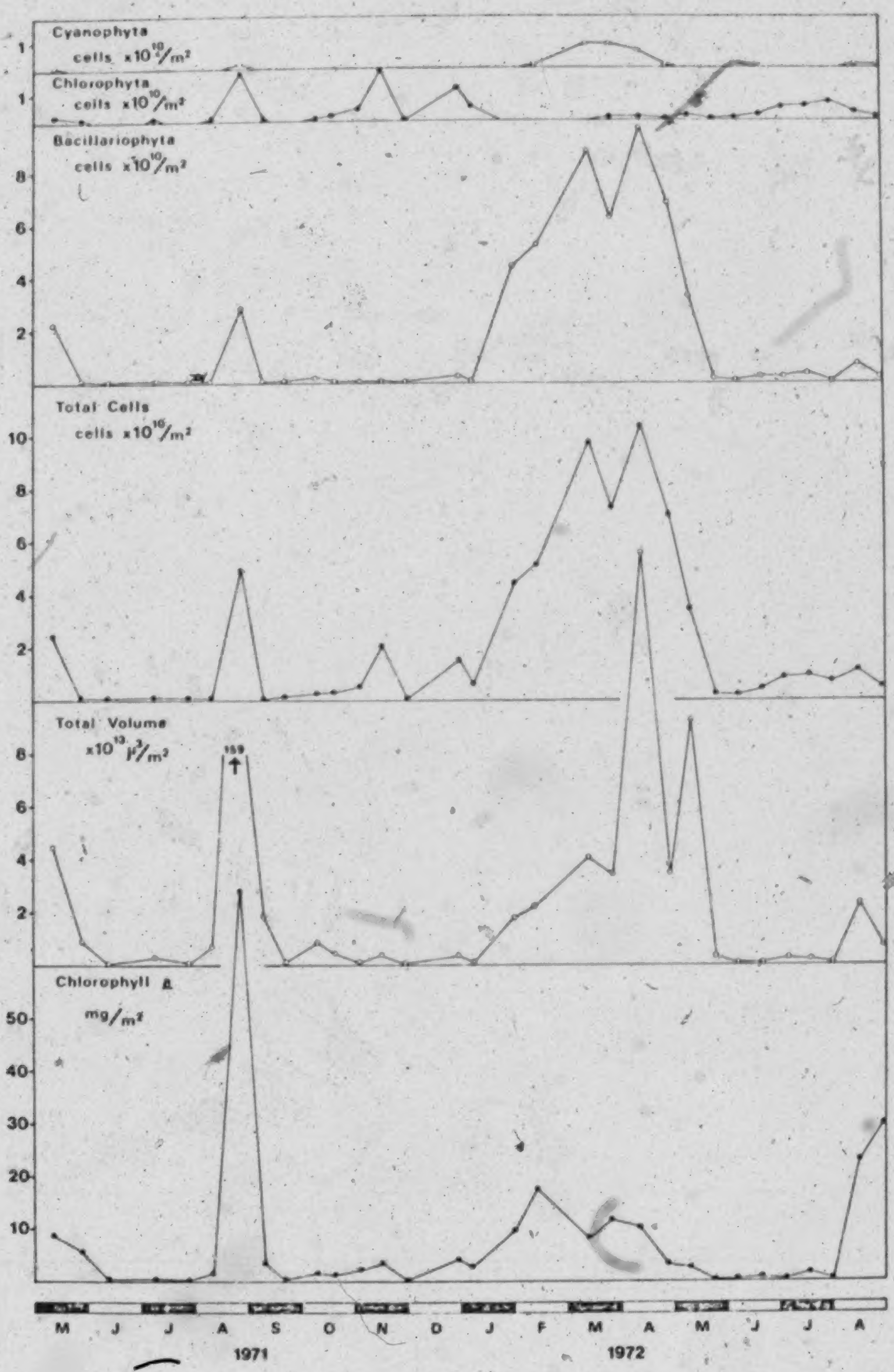
7

only dominant species with 4.5 x 10^8 cells/m^2 host stem. During late July, however, there was a rapid growth of from 2 x 10^8 to 12 x 10^8 cells/m^2 host stem in *A. minutissima* which had become dominant at this time. *A. minutissima* remained the most common diatom through the first half of August, although *Rivularia* sp. was the dominant algal species. *Rivularia* sp., which occurred only once during 1971, was reported in the population from late June through August in 1972. During August *Epithemia turgida*, and to a lesser extent, *Epithemia sorex*, experienced a rapid growth phase. *E. turgida* was dominant by the end of the month with 4.6 x 10^8 cells/m^2 host stem amounting to 26% of the total population. *Achnanthes minutissima*, *Cocconeis placentula*, and *Rivularia* sp. were also common at the end of August, the termination of the study.

Site Point Alison (PA)

Sampling commenced at the heated site PA in May 1971 as the spring maximum was beginning to decline toward a summer minimum (Figure 13). By early June this minimum, which remained until late August, had occurred. In late August there was a very rapid increase in standing crop size. This late summer/early autumn maximum was followed by just as rapid a decrease to pre-maximum standing crop levels. Two small autumn peaks in November and in December were showed by both chlorophyll a content and total cell numbers and to a lesser extent by total cell volume. The increase in standing crop during January and early February was registered by all three standing crop parameters. Chlorophyll a content attained a maximum in mid-February and then gradually declined, with a small peak in March, until a summer minimum was reached in late May. Total cell numbers however, continued to increase through February and March until the

FIGURE 13. Standing crop of the epiphyton at site PA expressed as per m^2 *Scirpus* sp. stem from May 1971 through August 1972.


Cyanophyta
cells x10¹⁰/m²
1
Chlorophyta
cells x10¹⁰/m²
1
Bacillariophyta
cells x10¹⁰/m²
8
6
4
2
Total Cells
cells x10¹⁰/m²
10
8
6
4
2
Total Volume
x10¹³ µ³/m²
159
8
6
4
2
Chlorophyll a
mg/m²
50
40
30
20
10
M
J
J
A
S
O
N
D
J
F
M
A
M
J
J
A
1971
1972

first of two spring peaks occurred in mid-March. Total cell volume paralleled cell numbers, but the mid-March peak was very small while the second peak in mid-April was much larger. After this second spring peak in mid-April, total cell numbers decreased towards a summer minimum. Total cell volume, however, declined during late April but showed a large peak in early May. The summer minimum which commenced in late May, was shown by all three standing crop parameters. This minimum lasted until early August when chlorophyll a content showed a marked increase which was at first paralleled by the other two parameters but towards the end of the month total cell numbers and total cell volume showed a slight decline while chlorophyll a content continued to increase.

Fragilaria capucina was the most common species in early May as the spring maximum was beginning to decline with 9 x 10^9 cells/m^2 host stem accouting for 41% of the total population. Other common algae at this time included *Diatoma elongatum* (16% of the total population), *Fragilaria construens* var. *construens* (19%), *Fragilaria construens* var. *venter* (10%), and *Mougeotia* sp. (8%). By late May the standing crop had declined significantly as all three of the above mentioned *Fragilaria* spp. as well as *Mougeotia* sp. had virtually disappeared. *Diatoma elongatum* was the dominant species during this period accounting for 23% of the total population even though it had declined from 36 x 10^8 cells/m^2 host stem to 3 x 10^8 cells/m host stem. The other important species during late May were *Cocconeis placentula* and *Spirogyra* sp. *Fragilaria construens* var. *venter* reappeared in June and by the middle of the month shared dominance with *Cocconeis placentula* and *Diatoma elongatum*. Towards the end of the month, *Fragilaria construens* var.

venter was the most common species as the other two species had declined in population size. By mid-July *Cocconeis placentula* had replaced *Fragilaria construens* var. *venter* as the dominant species (3.4×10^8 cells/m^2 host stem, 24% of the total population). From mid-July until late October, with the exception of late August, *Cocconeis placentula* was the most common species, often accounting for more than 80% of the total population. In late August, an influx of filamentous members of the Chlorophyta, *Oedogonium* sp. (17×10^9 cells) and *Spirogyra* sp. (0.8×10^9 cells) and their associated secondary epiphytes, i.e. epiphytes growing attached to epiphytes, caused a large, late summer/early autumn standing crop maximum. The secondary epiphytes were dominated by *Synedra pulchella*. However, *Cocconeis placentula* was still a common species with 5.7×10^9 cells/m^2 (12% of the total population). During early September this large population of *Oedogonium* sp., *Spirogyra* sp. and associated epiphytes underwent a drastic decline. *Oedogonium* sp. dropped to 4×10^7 cells/m^2 host stem, *Spirogrya* sp. dropped to 19×10^7 cells/ m^2 host stem, while *Synedra pulchella* disappeared entirely. Although *Cocconeis placentula* experienced a 10-fold decrease to 5.2×10^8 cells/m^2 host stem, it accounted for 60% of the total population. In early October, *Stigeoclonium tenue* increased in population size and by the end of the month was the dominant species (4.5×10^9 cells/m^2 host stem) accounting for 70% of the total population. During early November *Stigeoclonium tenue* continued to increase until, with 20×10^9 cells/m^2 host stem, it accounted for 95% of the total population; however, by the end of the month it had completely disappeared. *Cocconeis placentula* again became the most common species (1.2×10^7 cells/m^2 host stem), with the disappearance of *Stigeoclonium tenue*. By late December it again became a minor part of the population when *Stigeoclonium tenue* reappeared and became the most important species with 12×10^9 cells/m^2 host stem accounting for 80% of the total population. During January, *Stigeoclonium tenue* decreased and by early February had disappeared. This decrease of *S. tenue* corresponded to an increase in both *Diatoma elongatum* and *Gomphonema olivaceum* which had become the most common species (during February) (13×10^9 cells/m^2 host stem, 25% of total population and 9×10^9 cells/m^2 host stem, 17% of the total population, respectively). Both *Fragilaria capucina* and *Oscillatoria tenuis* were recorded in the population in February. By mid-March the former was the dominant species, accounting for 49% of total population with 47×10^{10} cells/m^2 host stem while the latter was one of several common species with 9×10^{10} cells/m^2 host stem. The two other common species during the first of the two spring peaks in total cell number were *Diatoma elongatum* (7×10^{10} cells/m^2 host stem) and *Fragilaria vaucheriae* (6×10^{10} cells/m^2 host stem). *Fragilaria capucina* remained the dominant species until late May and the onset of the summer minimum. The second peak in total cell numbers which occurred in mid-April was due primarily to large increases in both *Fragilaria capucina* (5×10^{10} cells/m^2 host stem from 2.2×10^{10} cells/m^2 host stem) and *Diatoma elongatum* (1.1×10^{10} cells/m^2 host stem from $.5 \times 10^{10}$ cells/m^2 host stem). After this second peak in mid-April, the total cell numbers rapidly declined, culminating with the summer minimum in late May. The total cell volume peak in early May was not caused by the two major species.

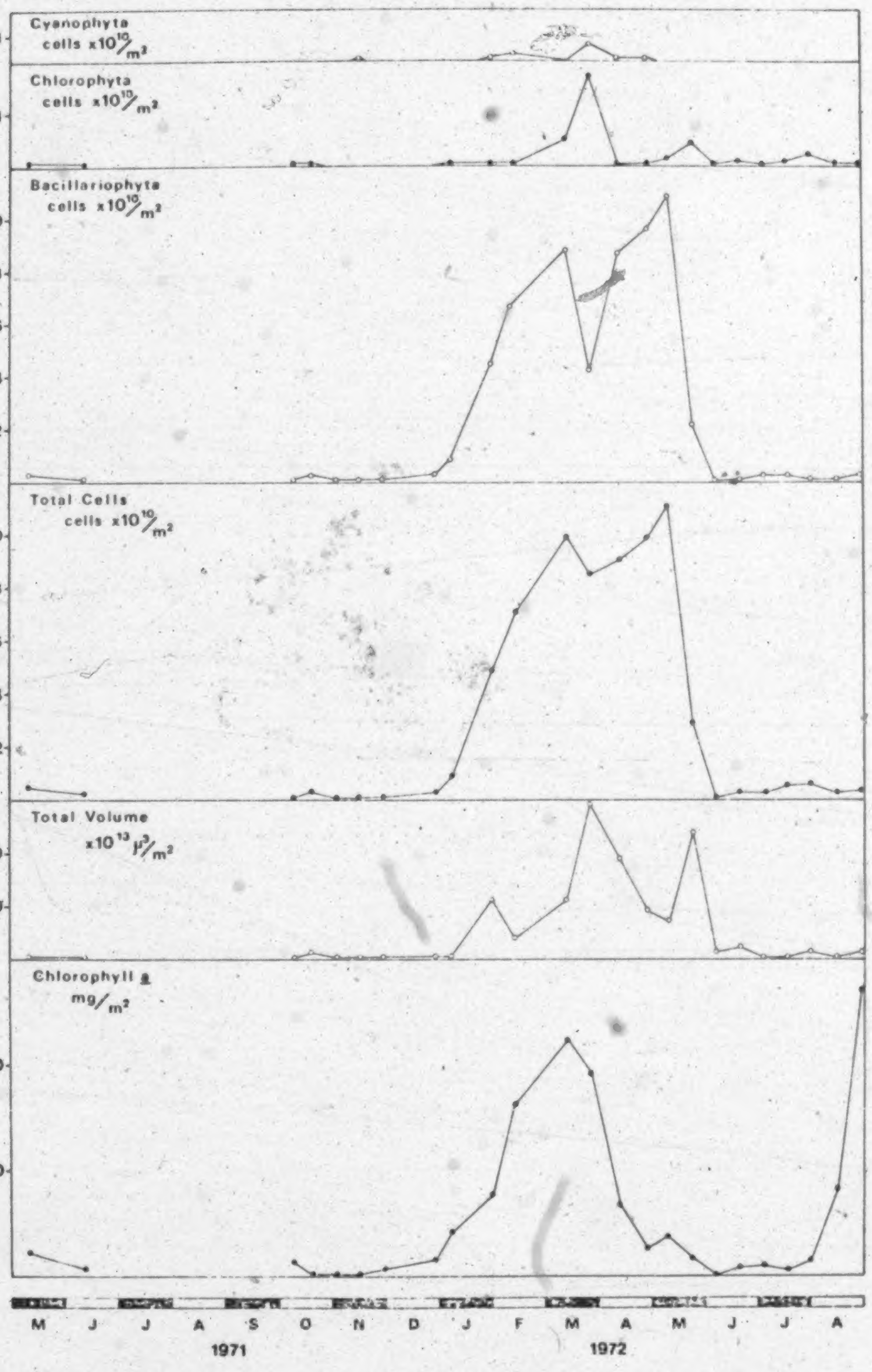
Fragilaria capucina and *Diatoma elongatum*, as both were undergoing a rapid decline at this time, but rather to a sudden influx of *Spirogyra* sp. (1.1×10^9 cells/m^2 host stem). *Diatoma elongatum* was the most common species, with 6×10^8 cells/m^2 host stem, when the period of summer minimum began in late May. *Zygnema* sp. was recorded during late May but was never numerically important and had disappeared by early June. During the month of June *Gomphonema gracile*, *Gomphonema parvulum*, and *Cocconeis placentula* were common; however, *Stigeoclonium tenue* was the dominant species with 6.0×10^8 cells/m^2 host stem and remained dominant through late August and the termination of the study. In July and early August *Cocconeis placentula* and *Gomphonema gracile* were common species. During mid-August when all three parameters were recording an increase in standing crop, *Gomphonema gracile* increased in population size until it shared dominance with *Stigeoclonium tenue* (2.9×10^9 cells/m^2 host stem and 2.5×10^9 cells/m^2 host stem, respectively). By the end of August when the chlorophyll a content continued to increase and total cell numbers and total cell volume decreased slightly, *Stigeoclonium tenue* once again became the most common species (31 % of total population) while *Gomphonema gracile* had declined nearly 50% in population size. and accounted for only 18% of the total population. *Gomphonema parvulum* (18%) and *Cocconeis placentula* (15%) were other common species. Both *Oedogonium* sp. and *Spirogyra* sp. were again recorded in the flora at this time, but not in large numbers.

Site Wabamun Outlet (WO)

At site WO the large spring peak had probably already occurred by the time sampling began in early May, 1971, since all three parameters showed a small standing crop (Figure 14). The major algae during early May were *Stigeoclonium tenue* (1.8×10^9 cells/m^2 host stem, 35% of the total population) and *Diatoma elongatum* (1.5×10^9 cells/m^2 host stem, 29% of total population). By early June the population of *Stigeoclonium tenue* had declined slightly but it accounted for 51% of the total population since the total cell numbers had also declined. During May *Cocconeis placentula* increased in numbers until by early June it was responsible for 46% of the total population, and shared dominance with *Stigeoclonium tenue*.

Sampling was suspended from late June through late September due to the inaccessibility of the site. From early October, when sampling again commenced, until early January, there was a minimum shown by all three standing crop parameters. Total cell numbers and chlorophyll a content showed a rapid increase during January and February until a peak was attained in mid-March. However, total cell volume showed an irregular increase from January with a small peak in early February and the major peak in late March. This peak was followed by a period of rapid decline in total cell volume until late May when a second major peak occurred. After the major peak in mid-March, chlorophyll a content showed a rapid decline; only a small peak was recorded in early May when total cell numbers reached a second major peak. During early June all three parameters recorded a summer minimum in standing crop. Both total cell numbers and total cell volume remained at this minimum through the termination of the study in late August; however, there was a rapid increase in the chlorophyll a content during the month of August. It reached a maximum at the end of the month.

FIGURE 14. Standing crop of the epiphyton at site WO expressed as per m^2 *Scirpus* sp. stem from May 1971 through August 1972.


Cyanophyta
cells x10^{10}/m^2
1
Chlorophyta
cells x10^{10}/m^2
1
Bacillariophyta
cells x10^{10}/m^2
10
8
6
4
2
Total Cells
cells x10^{10}/m^2
10
8
6
4
2
Total Volume
x10^{13} μ^3/m^2
20
10
Chlorophyll a
mg/m^2
20
10
M
J
J
A
S
O
N
D
J
F
M
A
M
J
J
A
1971
1972

Cocconeis placentula was the major species during the long autumn and early winter minimum, accounting for from 61% to 89% of the total population. *Stigeoclonium tenue* declined very rapidly during October and had disappeared by early November. This suggested that it had reached a peak some time before October. From early November until early January when there was a rapid increase in standing crop; both total cell numbers and chlorophyll a content showed a gradual increase. The relative importance of *Cocconeis placentula* declined during the initial stages of the rapid standing crop increase (89% to 35%) even though the population was increasing (2.7×10^9 cells to 3.2×10^9 cells/m^2 host stem) This was due to the rapid growth of both *Gomphonema gracile* (1.8×10^9 cells/m^2 host stem) and *Gomphonema parvulum* (1.6×10^9 cells/m^2 host stem). In early February, *Gomphonema longiceps* attained dominance with 1.3×10^{10} cells/m^2 host stem (28% of the total population) but my mid-February it had been replaced as the most common species by *Fragilaria capucina* (1.6×10^{10} cells/m^2 host stem, 23% total population) which had first appeared in the population in early February. *Gomphonema longiceps*, while still a common species, had declined to 0.5×10^{10} cells/m^2 host stems. *Gomphonema olivaceum* reached its peak of 0.8×10^{10} cells/m^2 host stem during mid-February. *Fragilaria capucina* was the dominant species (3×10^{10} cells/m^2 host stem, 30% of the total population) during the first spring peak in total cell numbers, while *Rhoicosphenia curvata*, *Diatoma vulgare*, *Stigeoclonium tunue*, and *Fragilaria vaucheriae* were also common. During late March there was a large decline in the diatom population but this was largely offset by an increase in the chlorophycean population.

Stigeoclonium tenue assumed dominance with 3.4 x 10^{10} cells/m^2 host stem, while *Rhoicosphenia curvata* with 1.7 x 10^{10} cells/m^2 host stem and *Fragilaria capucina* with 0.7 x 10^{10} cells/m^2 host stem were the most common members of the Bacillariophyta. However, by mid-April both *Stigeoclonium tenue* and *Rhoicosphenia curvata* had virtually disappeared as *Fragilaria capucina* with 4.4 x 10^{10} cells/m^2 host stem (49% of the total population) and *Fragilaria vaucheriae* with 1.4 x 10^{10} cells/m^2 host stem assumed dominance. The second spring peak in total cell numbers (11 x 10^{10} cells/m^2 host stem) during early May was dominated by *Fragilaria capucina* (62% of total population) while *Diatoma elongatum* accounted for 16% of the total population. During late May, as total cell numbers were rapidly decreasing, total cell volume attained its second major spring peak. This apparent contradiction was caused primarily by an increase in the population of large-celled members of the Chlorophyta, *Spirogyra* sp. *Mougeotia* sp., and *Zygnema* sp. which more than offset the volume loss due to declining cell numbers. *Fragilaria capucina*, however, retained dominance with 0.8 x 10^{10} cells/m^2 host stem (28% of the total population). All three standing crop parameters recorded a summer minimum which occurred in early June. At this time *Zygenema* sp., with 2 x 10^8 cells/m^2 host stem, accounted for 34% of the total population while *Oedogonium* sp. and *Cocconeis placentula* were also common. By late June *Stigeoclonium tenue* had assumed dominance (45% of the total population) with 1.7 x 10^9 cells/m^2 host stem while *Cocconeis placentula* accounted for 29% of the total population. During July and August *Cocconeis placentula* and then *Stigeoclonium tenue* assumed dominance.

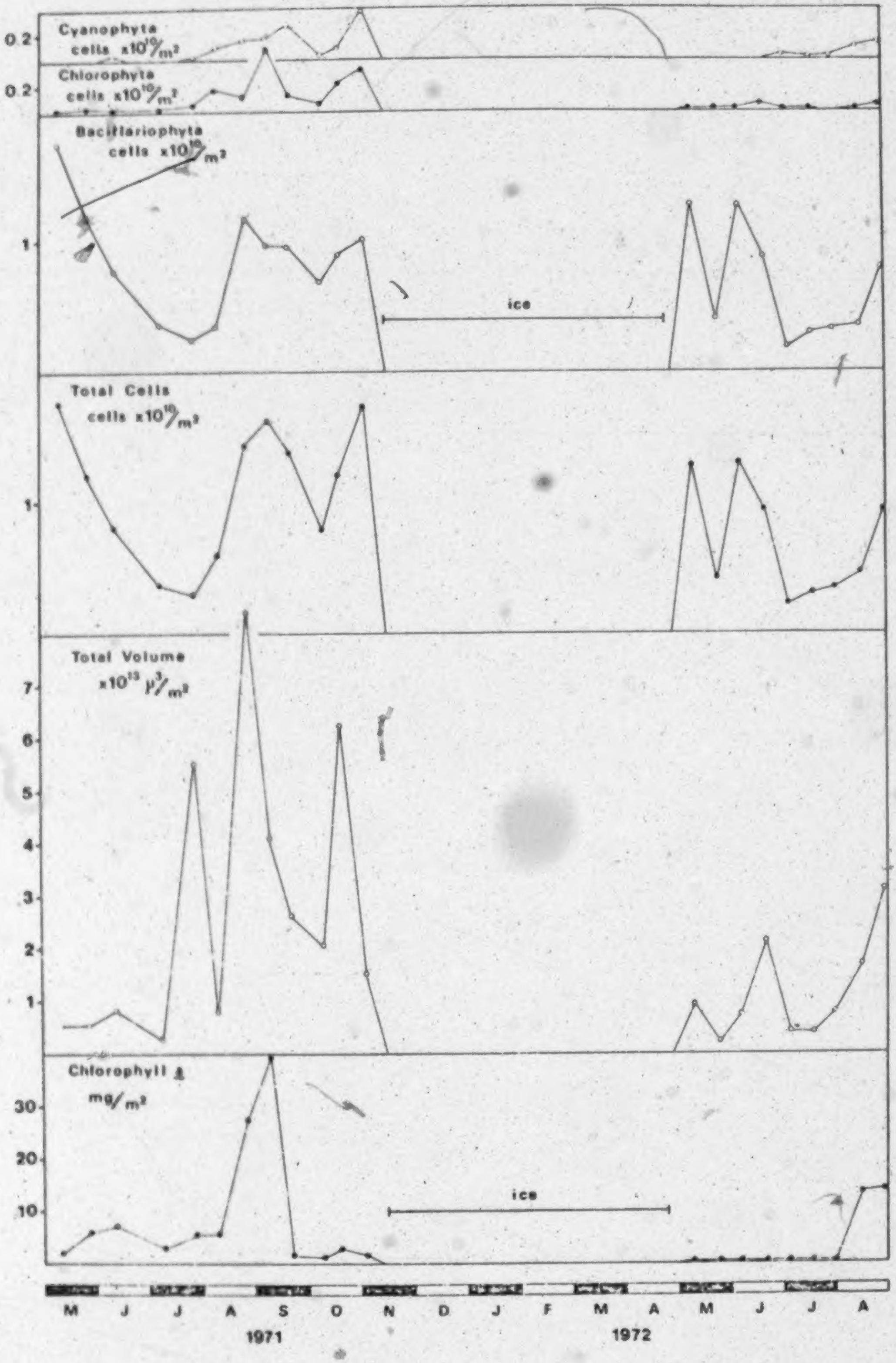
During early July *Cocconeis placentula* was the most common species accounting for 61% of the total population; however, by late July *Stigeoclonium tenue*, which had increased in population size, shared dominance with *Cocconeis placentula*. Each species accounted for 40% of the total population. During August *Stigeoclonium tenue* was the dominant species until the later part of the month when the two species (*C. placentula* and *S. tenue*) again shared dominance.

Site Sundance Inlet (SI)

During 1971 only total cell numbers showed a spring maximum, which declined until early July when a summer minimum began (Figure 15). Both total cell volume and chlorophyll a content remained fairly constant until mid-August when all three parameters showed a rapid increase in standing crop size. Total cell volume attained the first of two autumn peaks in late August. By mid-September, when the other two parameters showed a peak, total volume was declining rapidly. Chlorophyll a content dropped to minimum values after the peak in mid-September and did not register the mid-October peak in total cell volume or the early November peak in total cell numbers.

The spring maximum in total cell numbers was dominated by members of the Bacillariophyta, particularly *Diatoma elongatum* and *Achnanthes minutissima*. The former algae accounted for over 50% of the total population in May, even though its numbers declined from 10.3×10^9 cells to 5.8×10^9 cells/m^2 host stem during the month. The population of *Diatoma elongatum* continued to decline during June and by early July was present only in very small numbers. *Synedra acus* assumed

FIGURE 15. Standing crop of the epiphyton at site SI expressed as per m^2 *Scirpus* sp. stem from May 1971 through August 1972. Period of ice cover is indicated.


Cyanophyta
cells x10¹⁰/m²
0.2
Chlorophyta
cells x10¹⁰/m²
0.2
Bacillariophyta
cells x10¹⁰/m²
1
ice
Total Cells
cells x10¹⁰/m²
1
Total Volume
x10¹³ µ³/m²
7
6
5
4
3
2
1
Chlorophyll a
mg/m²
30
20
10
ice
M
J
J
A
S
O
N
D
J
F
M
A
M
J
J
A
1971
1972

dominance in mid-June with a peak of 1.5 x 10^9 cells/m^2 host stem (19% of total population) although *Diatoma elongatum* along with *Fragilaria capucina* and *Gomphonema parvulum* were also common. By early July there were no species that contributed more than 10% of the total population. Among the more common algal species were *Cymbella ventricosa*, *Melosira ambigua*, and *Synedra acus*. The large total cell volume peak in late July was caused by an influx of large celled members of the Chlorophyta. The most important species were *Oedogonium* sp. and *Mougeotia* sp. with population sizes of 5.6 x 10^8 and 1.0 x 10^8 cells/m^2 host stem respectively. *Oedogonium* sp. accounted for 19% of the total population and *Mougeotia* sp. accounted for 4% of the total population. *Epithemia turgida*, another large-celled algal species, was the most common diatom with 3 x 10^8 cells/m^2 host stem. During the early part of August, *Oedogonium* sp. and *Mougeotia* sp. virtually disappeared as *Rivularia* sp., *A. minutissima* and *Amphipleura pellucida* increased in numbers until each comprised 10% of the total population. The increase in total cell volume towards a peak in late August was paralleled by the other two parameters although they did not reach peaks until mid-September. In late August *A. minutissima* (4.1 x 10^9 cells/m^2 host stem), *Rivularia* sp. (1.5 x 10^9 cells/m^2 host stem), and *Synedra acus* (1.0 x 10^9 cells/m^2 host stem) were the most common species. *Mougeotia* sp., which declined in late August, increased in early September until it accounted for 20% of the total population with 3.2 x 10^9 cells/m^2 host stem. Both total cell numbers and chlorophyll a content reached a peak at this time. By the end of September, *Mougeotia* sp. had declined to 1.1 x 10^9 cells/m^2 host stem as *Lyngbya limnetica* (2.4 x 10^8 cells) and *Achnanthes minutissima* (2.7 x 10^8 cells/m^2 host stem) assumed dominance. Although the total cell numbers decreased only slightly there was a marked decline in both total cell volume and chlorophyll a content. The large celled algae (*Mougeotia* sp.) were replaced by cells with a much smaller volume (*Achnanthes minutissima* and *Lyngbya limnetica*). This could have also contributed to the decline in chlorophyll a content as cells of *Mougeotia* sp. have a much larger chloroplast than do either *Achnanthes minutissima* or *Lyngbya limnetica*. During October no species comprised more than 10% of the population with the exception of *Achnanthes minutissima* which with 1.7 x 10^9 cells/m^2 host stem accounted for 14% of the total population in the latter part of the month. In early November, as the water temperatures decreased from 5.6 to 2.8°C, *Mougeotia* sp. again became the most common species comprising 18% of the total population (3.1 x 10^9 cells/m^2 host stem). *Achnanthes minutissima* (1.8 x 10^9 cells/m^2 host stem), *Lyngbya limnetica* (1.5 x 10^9 cells/m^2 host stem), *Rivularia* sp. (1.1 x 10^9 cells/m^2 host stem) and *Anabaena* sp. (1.1 x 10^9 cells/m^2 host stem) were other common algae in early November. Ice formation in mid-November caused suspension of sampling at this site.

A spring maximum was registered during May and June 1972 in both total cell numbers and total cell volume, but as in 1971, chlorophyll a content did not show this maximum. A minimum occurred in early July but lasted only until the middle of August when all three parameters showed an increase in standing crop.

The spring maximum consisted of two peaks, one in early May and the other in early June. *Diatoma elongatum*, although it decreased during May was the dominant organism ranging from 49%

(6.2×10^9 cells/m^2 host stem) in early May to 37% (1.6×10^9 cells/m^2 host stem) towards the end of the month. The peak in early June was dominated by *Fragilaria capucina* (4.4×10^9 cells/m^2 host stem, 34% of the total population)and *Diatoma elongatum* (3.8×10^9 cells/m^2 host stem, 29% of the total population). *Gomphonema gracile* and *Achnanthes minutissima* were also common species during the spring maximum. After the second peak in early June the standing crop declined to reach a summer minimum in early July. During this decrease *Diatoma elongatum* with 1.6×10^9 cells/m^2 host stem (18% of total population) and *Synedra acus* with 1.0×10^9 cells/m^2 host stem (11% of total population) were the most common species. Through the summer minimum, no species accounted for more than 10% of the total population *Achnanthes minutissima, Amphipleura pellucida, Cocconeis placentula, Diatoma elongatum,* and *Nitzschia fonticola* were common, however. In early August, *Achnanthes minutissima* with 9.0×10^8 cells/m^2 comprised 28% of the population as the standing crop began to increase. By the middle of the month *Epithemia turgida* (5.7×10^8 cells/m^2 host stem) and *Anabaena* sp. (9.7×10^8 cells/m^2 host stem) had assumed dominance. These two species were also the most common species at the end of the month with 1.0×10^9 cells/m^2 host stem and 1.2×10^9 cells/m^2 host stem, respectively. Other common algae during this increase were *Achnanthes minutissima, Amphipleura pellucida, Gomphonema gracile, Rhopalodia gibba,* and *Mougeotia* sp.

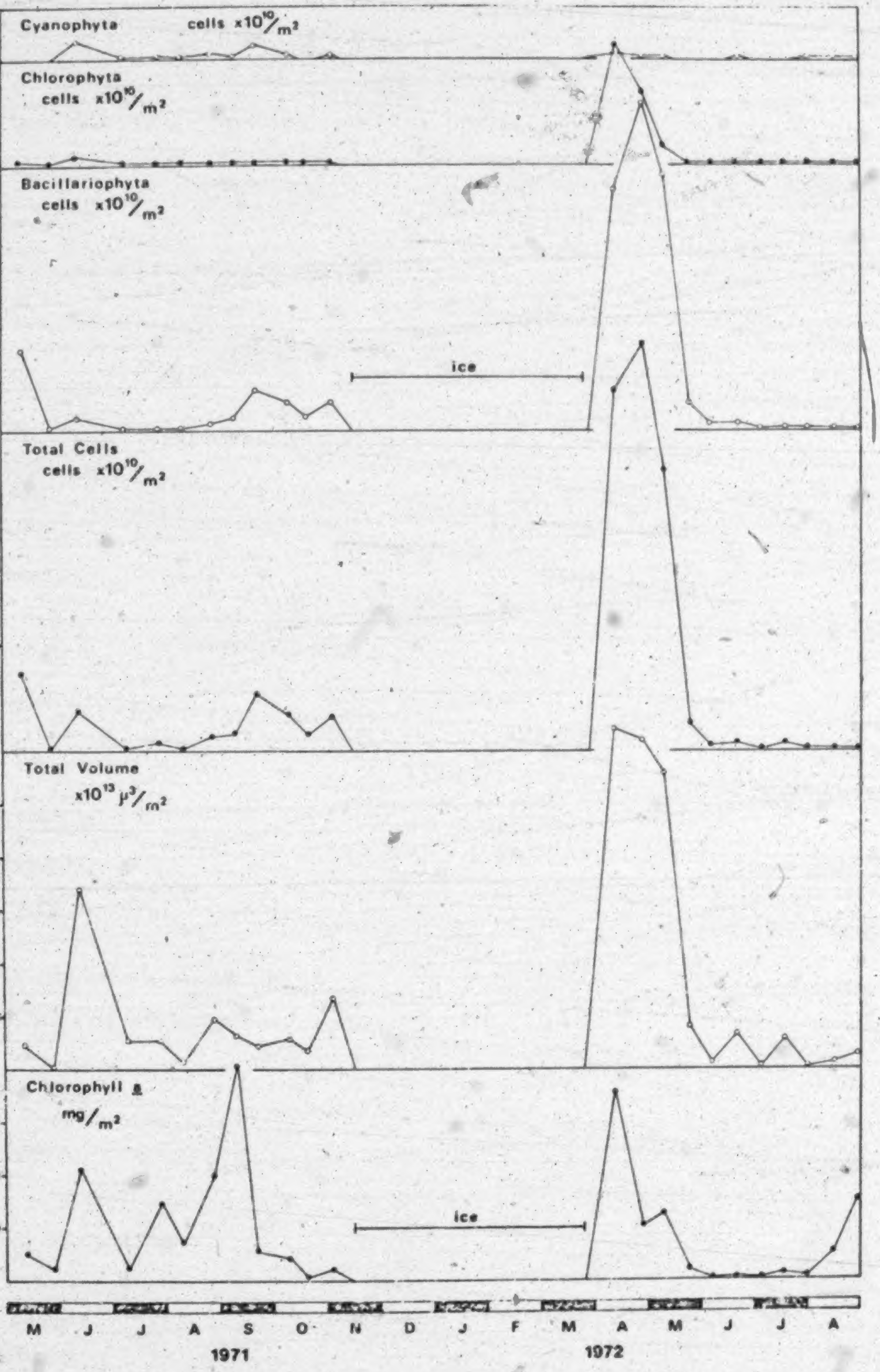
During the second summer there were far fewer chlorophycean and cyanophycean algae present. *Mougeotia* sp. was a major component of the flora during 1971 from mid-July until mid-November, while *Oedogonium* sp. was also recorded in small numbers during the same period. *Rivularia* sp. was also a dominant species during August, 1971. However, during the summer of 1972 *Mougeotia* sp., *Oedogonium* sp., and *Rivularia* sp. were only rarely recorded and then in very small numbers.

Site Goosequill Bay (GB)

Two spring peaks, one in early May and the other in mid-June, were registered by total cell numbers during 1971, but only the peak in mid-June was shown by all three parameters (Figure 16). The chlorophyll a content never showed the summer minimum that was registered in total cell numbers and total cell volume; instead the chlorophyll a content showed an irregular increase all summer towards a peak in early September. After this peak, the chlorophyll a content rapidly declined and remained low until ice formation which occurred in mid-November. Total cell numbers reached a peak in late September and a secondary peak in early November. The latter peak was also recorded in total cell volume, which showed an earlier peak late August.

The initial spring peak in total cell numbers was dominated by *Diatoma elongatum* with 2.2 x 10^{10} cells/m^2 host stem (26% of the total population) and *Fragilaria capucina* with 2.1 x 10^{10} cells/m^2 host stem (25% of the total population) while *Fragilaria brevistrata* (1.1 x 10^{10} cells/m^2 host stem), *Achnanthes minutissima* (0.5 x 10^{10} cells/m^2 host stem), and *Gomphonema parvulum* (0.3 x 10^{10} cells/m^2 host stem) were also common. During late May, *Achnanthes minutissima* assumed dominance but by mid-June had been replaced by *Tolypothrix* sp. (1.5 x 10^{10} cells/m^2 host stem, 40% of the total population). An influx of cyanophycean and chlorophycean algae was responsible for

FIGURE 16. Standing crop of the epiphyton at site GB expressed as per m^2 *Scirpus* sp. stem from May 1971 through August 1972. Period of ice cover is indicated.


Cyanophyta
cells x10¹⁰/m²
4
2
Chlorophyta
cells x10¹⁰/m²
5
Bacillariophyta
cells x10¹⁰/m²
20
10
ice
Total Cells
cells x10¹⁰/m²
20
10
Total Volume
x10¹³ µ³/m²
50
40
30
20
10
Chlorophyll a
mg/m²
30
20
10
ice
M
J
J
A
S
O
N
D
J
F
M
A
M
J
J
A
1971
1972

the standing crop peak in mid-June. Other common algal species during this peak included *Mougeotia* sp. (0.4 x 10^{10} cells/m^2 host stem), *Spirogyra* sp. (0.3 x 10^{10} cells/m^2 host stem), *Oedogonium* sp. (0.2 x 10^{10} cells/m^2 host stem), and *Diatoma elongatum* (0.2 x 10^{10} cells/m^2 host stem). These large-celled members of the Chlorophyta (*Mougeotia* sp. *Spirogyra* sp. and *Oedogonium* sp.) were primarily responsible for the large cell volume peak at this time. In early July, *Rivularia* sp. assumed dominance with 1.3 x 10^9 cells/m^2 host stem (33% of the total population). It retained a dominant position until its disappearance in early September. During the early part of July, *Cocconeis placentula*, *Synedra acus* and *Fragilaria vaucheriae* were all common. However, by the end of the month only *Cocconeis placentula* was still common since *Synedra acus* had disappeared and *Fragilaria vaucheriae* had declined to less than 5% of the total population. During early August *Cocconeis placentula* increased in population size until it shared dominance with *Rivularia* sp., each with 1.3 x 10^9 cells/m^2 host stem. During the latter part of the month there was a three-fold decrease in the *Cocconeis placentula* population, which coincided with a rapid growth in *Lyngbya limnetica*. *Lyngbya limnetica* together with *Rivularia* sp. were primarily responsible for the increase in the standing crop as measured by all three parameters, with 2.9 x 10^9 cells/m^2 host stem and 2.4 x 10^9 cells/m^2 host stem, respectively along with smaller pppulations of *Achnanthes minutissima* (1.2 x 10^9 cells/m^2 host stem) and *Gomphonema parvulum* (1.1 x 10^9 cells/m^2 host stem). In early September, during the chlorophyll a content peak, *Achnanthes minutissima* (5.3 x 10^9 cells/m^2 host stem), *Oscillatoria amonena* (2.1 x 10^9 cells/m^2 host stem) and *Fragilaria vaucheriae* (1.3 x 10^9 cells/m^2 host stem) were the most common species. During the latter part of the month total cell numbers reached an autumn maximum with *Achnanthes minutissima* (18×10^9 cells/m^2 host stem, 33% of the total population) and *Lyngybya limnetica* (13×10^9 cells/m^2 host stem, 24% of the total population) becoming the dominant species. During October, as all three parameters showed a decline in standing crop size, *Achnanthes minutissima* increased in dominance from 35% of the total population during early October to 46% of the total population in late October, although it decreased in total numbers. *Bulbochaete* sp. was present throughout October, although it never became a common member of the population. The standing crop peak in early November was dominated by *Achnanthes minutissima* with 7.4×10^9 cells/m^2 host stem (24% of the total population), *Diatoma elongatum* with 3.4×10^9 cells/m^2 host stem (11%) and *Fragilaria vaucheriae* with 4.5×10^9 cells/m^2 host stem (15%).

In 1972 a large spring maximum which decreased to a minimum in early June was recorded by all three standing crop parameters. Total cell numbers remained low after the spring maximum through August. However, there was a rapid increase in chlorophyll a content during August. Total cell volume showed no distinct trend but rather fluctuated with peaks in late June, mid-July, and late August.

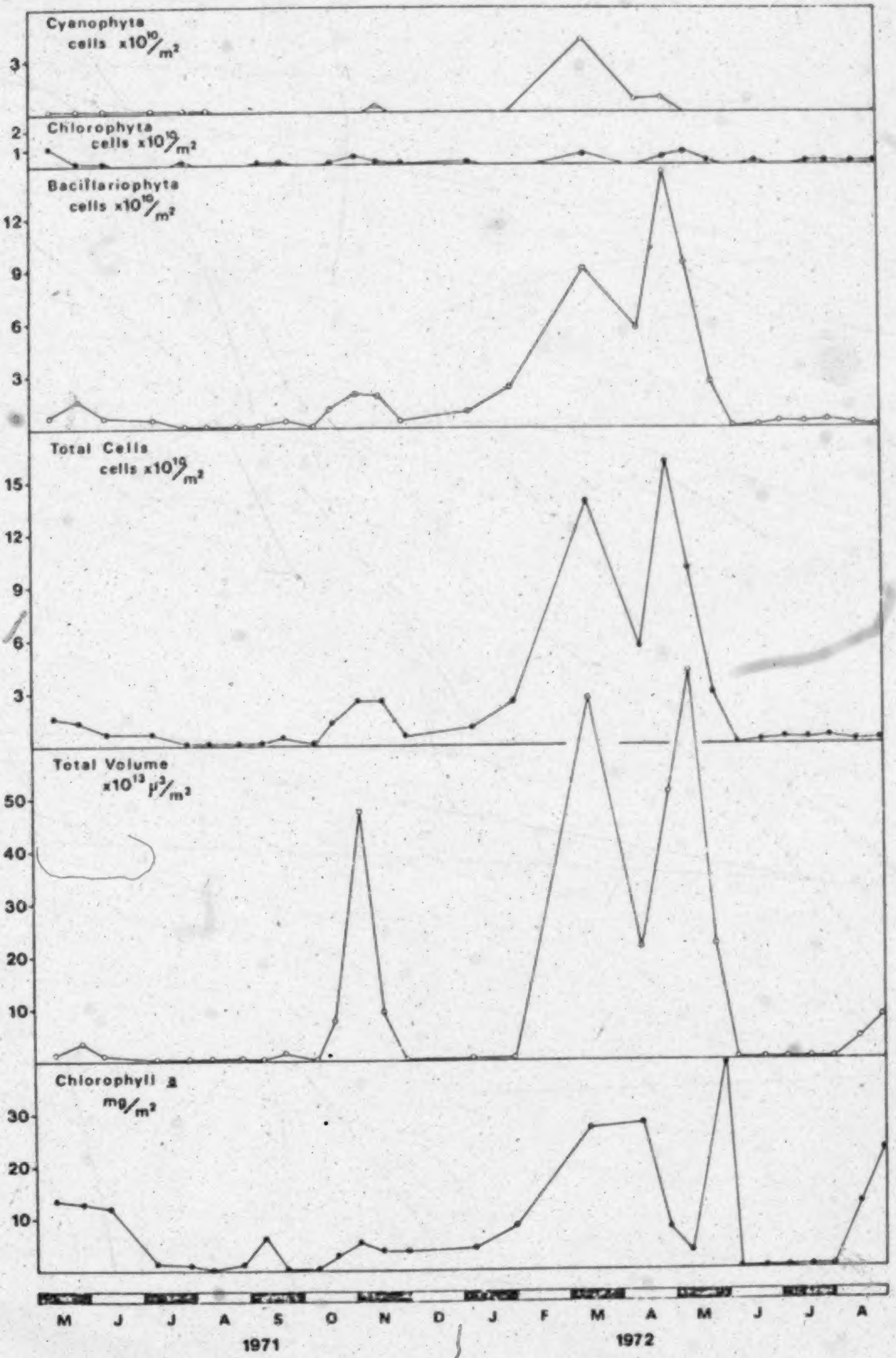
In early April 1972, *Draparnaldia glomerata* was the dominant species with 10.8×10^{10} cells/m^2 host stem (32% of the total population) but by the end of the month had declined to 6×10^{10} cells /m^2 host stem. *Fragilaria capucina*, which accounted for 16% of the population in early April, became the cominant species in the latter part of the month (10×10^{10} cells/m^2 host stem, 27% of the total population). Other common algae during the large spring peak in April were *Cymbella caespitosa, Diatoma elongatum,* and *Fragilaria vaucheriae.* During May, all three parameters recorded a rapid decline in standing crop with total cell numbers declining from 26 x 10^{10} cells/m^2 host stem in early May to 2 x 10^{10} cells/m^2 host stem in late May. *Cymbella caespitosa* reached a maximum in early May and assumed dominance with 7.8 x 10^{10} cells/m^2 host stem (30% of the total population), while *Fragilaria capucina* (3.9 x 10^{10} cells/m^2 host stem), *Diatoma elongatum* (2.7 x 10^{10} cells/m^2 host stem), *Fragilaria vaucheriae* (1.9 x 10^{10} cells/m^2 host stem), and *Draparnaldia glomerata* (1.5 x 10^{10} cells/m^2 host stem) were also common. The rapid decline in cell numbers during May was caused primarily by the disappearance of *Draparnaldia glomerata* and the large drop in the population size of *Diatoma elongatum* (3 x 10^9 cells/m^2 host stem) and *Fragilaria vaucheriae* (2 x 10^9 cells/m^2 host stem). *Fragilaria capucina* assumed dominance (43% of the total population) at this time with a population that was less than 1/3 of its former size (1.1 x 10^{10} cells/m^2 host stem). This decline continued into early June as the total population decreased to 6 x 10^9 cells/m^2 host stem, with *Fragilaria capucina* accounting for 60% of the total population. By late June, *Fragilaria vaucheriae* assumed dominance while spring dominants, *Cymbella caespitosa, Fragilaria capucina,* and *Diatoma elongatum* disappeared. In late July, *Stigeoclonium tenue* (1.5 x 10^9 cells/m^2 host stem), and *Cocconeis placentula* (1.1 x 10^9 cells/m^2 host stem) became the most common species. The latter species had been present in small numbers since ice break-up. Total cell numbers decreased slightly during August although both total cell volume and chlorophyll a content registered marked increases. In early August

Rivularia sp. and *Cocconeis placentula* were the dominant species (9.8×10^8 cells/m^2 and 8.5×10^8 cells/m^2 host stem, respectively) as *Stigeoclonium tenue* declined, disappearing by mid-August. In mid-August *Cocconeis placentula* and *Epithemia turgida*, which had been recorded in the flora in small numbers since June, together accounted for 70% of the total population (8.4×10^8 cells/m^2 host stem, respectively). These two species declined in population size towards the end of August as *Rivularia* sp. again became the dominant species (6.0×10^8 cells/m^2 host stem, 27% of the total population). *Spirogyra* sp. (2.2×10^8 cells/m^2 host stem) and *Gomphonema gracile* (2.1×10^8 cells/m^2 host stem) along with *Cocconeis placentula* (4.7×10^8 cells/m^2 host stem) and *Epithemia turgida* (3.0×10^8 cells/m^2 host stem) were also common at this time.

Site Sundance Outlet (SO)

By late June, 1971, a spring maximum as shown by chlorophyll a content and to a lesser extent by total cell volume and total cell numbers had disappeared (Figure 17). The summer minimum continued until early September when a small peak was registered by chlorophyll a content; however, the peak was not registered by either of the other two standing crop parameters. An autumn peak was recorded in total cell volume and paralleled by the other two standing crop parameters in early November. By mid-November both total cell volume and chlorophyll a content indicated a decrease in standing crop size although total cell numbers remained high. In late November a winter minimum occurred, which lasted until mid-March, when the first of two spring peaks was recorded by all three of the standing crop parameters.

FIGURE 17. Standing crop of the epiphyton at site SO expressed as per m^2 *Scirpus* sp. stem from May 1971 through August 1972.


Cyanophyta
cells x10^10/m²
3
Chlorophyta
cells x10^10/m²
2
1
Bacillariophyta
cells x10^10/m²
12
9
6
3
Total Cells
cells x10^10/m²
15
12
9
6
3
Total Volume
x10^13 µ³/m²
50
40
30
20
10
Chlorophyll a
mg/m²
30
20
10
M
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J
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M
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J
A
1971
1972

The second peak, however, was shown at a different time by each of the three parameters. During late April total cell numbers attained a peak, when total cell volume was still increasing and chlorophyll a content was declining. Two weeks later, in early May, total cell volume peaked when total cell numbers were dropping and chlorophyll a content had reached a minimum. During late May chlorophyll a content peaked while both total cell numbers and total cell volume were dropping rapidly. All three standing crop parameters showed a summer minimum beginning in early June. During August both chlorophyll a content and total cell volume showed an increase in standing crop, although total cell numbers showed no increase.

The small maximum in May 1971 was dominated first by *Stigeoclonium tenue* (9.9 x 10^9 cells/m^2 host stem, 62% of the total population) and then by *Diatoma elongatum* (5.0 x 10^9 cells/m^2 host stem, 38% of the total population) towards the latter part of the month when *Stigeoclonium tenue* disappeared. During mid-June, *Gomphonema gracile* assumed dominance (22% of the total population) with 1.7 x 10^9 cells/m^2 host stem, even though it had not been recorded in the population during May. *Gomphonema parvulum* with 1.1 x 10^9 cells/m^2 host stem and *Anabaena* sp. with 1.2 x 10^9 cells/m^2 host stem were common in June. By early July, *Cocconeis placentula* (3.6 x 10^9 cells/m^2 host stem) had replaced *Gomphonema gracile* (1.1 x 10^9 cells/m^2 host stem) as the most common species, accounting for 58% of the total population. During late July and August *Cocconeis placentula* accounted for 81% to 91% of the total population. In early September *Cocconeis placentula* declined in importance although it remained the dominant species

(10×10^8 cells/m^2 host stem, 45% of the total population), as *Gomphonema gracile* (3×10^8 cells/m^2 host stem) and *Stigeoclonium tenue* (6×10^8 cells/m^2 host stem) became other common algal species. Although the total cell number doubled from 2.2×10^9 cells/m^2 host stem to 4.6×10^9 cells/m^2 host stem during mid-September, the relative importance of the more common species remained virtually unchanged. In early October there was a decrease in standing crop as *Stigeoclonium tenue* disappeared and *Gomphonema gracile* decreased to less than 5% of total population. During this period, *Cocconeis placentula* accounted for 77% of the total population (6.5×10^8 cells/m^2 host stem). During mid-October all three parameters showed an increase in standing crop size with a peak in early November. *Cocconeis placentula* with 6.8×10^9 cells/m^2 host stem (35% of total population) and *Gomphonema gracile* with 7.2×10^9 cells/m^2 host stem (36% of total population) were the dominant species during this peak. By late November *Gomphonema gracile* had assumed sole dominance (2.2×10^9 cells/m^2 host stem, 44% of the total population) although *Cocconeis placentula* remained an important member of the flora (1.6×10^9 cells/m^2 host stem, 32% of the total population). During January, *Rhoicosphenia curvata* increased rapidly in population size and by February 1 accounted for 51% of the total population with 12.7×10^9 cells/m^2 host stem, having replaced *Gomphonema gracile* as the dominant species. During February and early March there was a rapid increase in all three standing crop parameters with total cell numbers and total cell volume reaching the first of two spring peaks on March 12. The increase was caused by a rapid growth of *Oscillatoria rubescens* (4.1×10^{10} cells/m^2 host stem, 29% of total population) and

Melosira varians (3.6 x 10^{10} cells/m^2 host stem, 26% of the total population). Although *Rhoicosphenia curvata* had increased to 2.2 x 10^{10} cells/m^2 host stem, it had declined to 16% of the total population. *Diatoma vulgare* (1.5 x 10^{10} cells/m^2 host stem) and *Fragilaria brevistriata* (0.9 x 10^{10} cells/m^2 host stem) were also common during this mid-March peak. There was a sharp decline in the total cell numbers and total cell volume during late March and early April while the chlorophyll a content had declined only slightly. In early April *Melosira varians* with 1.9 x 10^{10} cells/m^2 host stem was the most common species (34% of the total population), as *Oscillatoria rubescens* decreased to less than 2% of the total population. During late April total cell numbers reached a peak as total cell volume was increasing but chlorophyll a content was declining. *Fragilaria capucina*, which was first recorded in the population in early April, was the dominant species (6 x 10^{10} cells/m^2 host stem, 38% of the total population) while *Diatoma elongatum* (3.2 x 10^{10} cells/m^2 host stem) and *Diatoma vulgare* (1.4 x 10^{10} cells/m^2 host stem) were also common at this time. In early May total cell volume reached a second spring peak although total cell numbers were declining and chlorophyll a content was at a minimum. Although *Fragilaria capucina* and *Diatoma elongatum* were the dominant species with 2.4 x 10^{10} cells/m^2 host stem, the increase in cell volume was attributed to an influx of *Oedogonium* sp. (4.1 x 10^9 cells/m^2 host stem), *Spirogyra* sp. (3.0 x 10^9 cells/m^2 host stem) and to a lesser extent *Cynbella caespitosa* (13 x 10^9 cells/m^2 host stem) and *Synedra pulchella* (3.7 x 10^9 cells/m^2 host stem). In late May chlorophyll a content reached a maximum while both cell volume and total cell numbers were declining towards the summer minimum. The most common algal species were *Diatoma elongatum* with 9.1 x 10^9 cells/m^2 host stem (31% of the total population), *Cymbella caespitosa* with 3.2 x 10^9 cells/m^2 host stem (11% of the total population), and *Fragilaria capucina* with 2.9 x 10^9 cells/m^2 host stem (10% of the total population). All three standing crop parameters showed the summer minimum occurring in early June. During the 1972 summer minimum as with the summer minimum in 1971 *Cocconeis placentula* was the dominant species accounting for 39% (June 6) to 67% (17 July) of the total population, while *Gomphonema gracile* was the other common species (19% on 20 June to 34% on 4 July of the total population). During the month of August both cell volume and chlorophyll a content showed an increase in standing crop although total cell numbers remained low. The rapid increase in these two paramenters corresponded to an increase in *Oedogonium* sp. and *Spirogyra* sp. which shared dominance with *Cocconeis placentula* by the end of the month with 5.5 x 10^8 cells/m^2 host stem, 5.3 x 10^8 cells/m^2 host stem, and 6.1 x 10^8 cells/m^2 host stem respectively.

II. Calculation of the Standing Crop

Both monthly and yearly (September, 1971 to August, 1972) means were calculated for each of the three measured standing crop parameters (Table 7, 8, 9). The two stations affected by the thermal discharge from the Wabamun Power Plant had mean yearly standing crops ranging from five times (cellvolume PA: WI) to nine times (chlorophyll a content PA: WI and WO: WI) greater than the undisturbed control site WI. The undisturbed control site was from 3 times (chlorophyll a content WI: SC) to 5 times (total cell numbers WI: SC) greater

TABLE 7

Monthly and Yearly Standing Crop Means as measured by Chlorophyll a Content (mg/m^2 host stem)

Site	May, 1971	June	July	August	September	October	November	December	January, 1972	February	March	April	May	June	July	August	Yearly Mean Sept. '71-Aug. '72
WO	2.0	.88	-	-	-	.84	.48	1.73	4.2	12.0	20.9	4.8	2.81	.54	.85	12.3	5.59
PA	7.41	.67	.70	37.9	1.89	1.45	1.94	4.06	2.76	13.8	10.0	6.71	1.54	.58	1.25	18.0	5.33
WI	9.69	.42	2.38	4.58	3.56	.79	.45	ice	ice	ice	ice	.19	.39	.32	.21	2.09	.67
SC	1.97	.93	.22	1.71	.95	.59	ice	ice	ice	ice	ice	ice	no sedges	.14	.19	.76	.22
SI	4.17	7.36	4.41	16.9	20.6	2.20	.65	ice	ice	ice	ice	ice	.31	.38	.35	9.2	2.81
GB	3.94	21.4	8.88	13.8	24.1	3.17	.88	ice	ice	ice	ice	ice	7.44	.30	.70	7.2	5.57
SO	13.2	12.1	1.55	.87	3.58	1.51	4.50	-	4.50	88.3	27.3	18.1	21.7	.20	.51	12.2	9.31

TABLE 8

Monthly and Yearly Standing Crop Means as measured by Total Cell Numbers (x10^7)

Site	May, 1971	June	July	August	September	October	November	December	January, 1972	February	March	April	May	June	July	August	Yearly Mean Sept.'71-Aug.'72
WO	519	242	-	-	-	214	63	310	889	5,952	9,193	9,424	7,059	217	422	417	3,105
PA	1,295	5	108	2,494	127	299	880	1,521	672	4,855	8,538	8,744	1,867	341	881	803	2,461
WI	3,770	205	139	499	426	806	450	ice	ice	ice	ice	2,552	1,286	290	256	370	536
SC	132	168	160	216	283	458	ice	ice	ice	ice	ice	ice	no sedges	161	165	189	105
SI	1,499	823	447	1,012	1,490	1,002	581	ice	ice	ice	ice	ice	859	1,126	269	594	493
GB	4,040	3,760	571	956	3,551	2,462	1,058	ice	ice	ice	ice	36,073	14,569	668	384	236	4,917
SO	1,507	791	372	123	346	678	1,870	-	1,072	2,536	13,919	10,818	6,508	137	381	331	3,509

TABLE 9

Monthly and Yearly Standing crop Means as measured by Total Cell Volumes ($x10^{10}$ μ^3)

Site	May, 1971	June	July	August	September	October	November	December	January, 1972	February	March	April	May	June	July	August	Yearly Mean Sept.'71-Aug.'72
WO	270	111	-	-	-	567	41	231	463	10,121	45,224	14,292	15,576	1,751	227	1,287	8,162
PA	2,719	2	205	80,054	1,007	655	178	333	151	2,029	3,762	9,596	4,807	123	269	1,080	1,999
WI	4,065	166	464	396	737	584	144	ice	ice	ice	ice	946	737	826	307	972	438
SC	85	120	33	201	545	429	ice	ice	ice	ice	ice	ice	no sedges	104	114	252	120
SI	543	820	2,898	4,631	3,389	4,152	503	ice	ice	ice	ice	ice	559	1,447	407	1,879	1,028
GB	2,378	34,358	5,491	5,465	5,556	4,572	4,488	ice	ice	ice	ice	63,456	31,894	3,897	3,105	1,623	9,883
SO	2,543	1,165	208	123	782	3,792	18,818	-	401	860	69,407	36,117	48,630	83	264	4,290	16,677

than the disturbed control site, indicating that human activity greatly reduced the epiphyton standing crop.

The greater mean yearly standing crop in the heated zone was also evident in the Sundance study area, with the heated site having a yearly mean of from 4 times (chlorophyll a content SO: SI) to 16 times (total cell volume SO: SI) greater than the non-heated site. The semi-heated site, GB, generally showed intermediate values with the exception of total cell numbers. The yearly mean was larger for GB than for the heated site SO, due primarily to the massive April 1972 population at the former.

The monthly standing crop means indicated that the populations in both the heated and non-heated sites were similar from May through October. The great difference in the mean yearly standing crop between the heated and non-heated sites was due to growth during the winter in the former while the the latter were under ice.

III. Relationship between Temperature and some of the Common Species

Many of the common species displayed a preference for either the ambient or the heated water sites. Several of these species were compared with corresponding water temperatures to observe any temperature-population correlations.

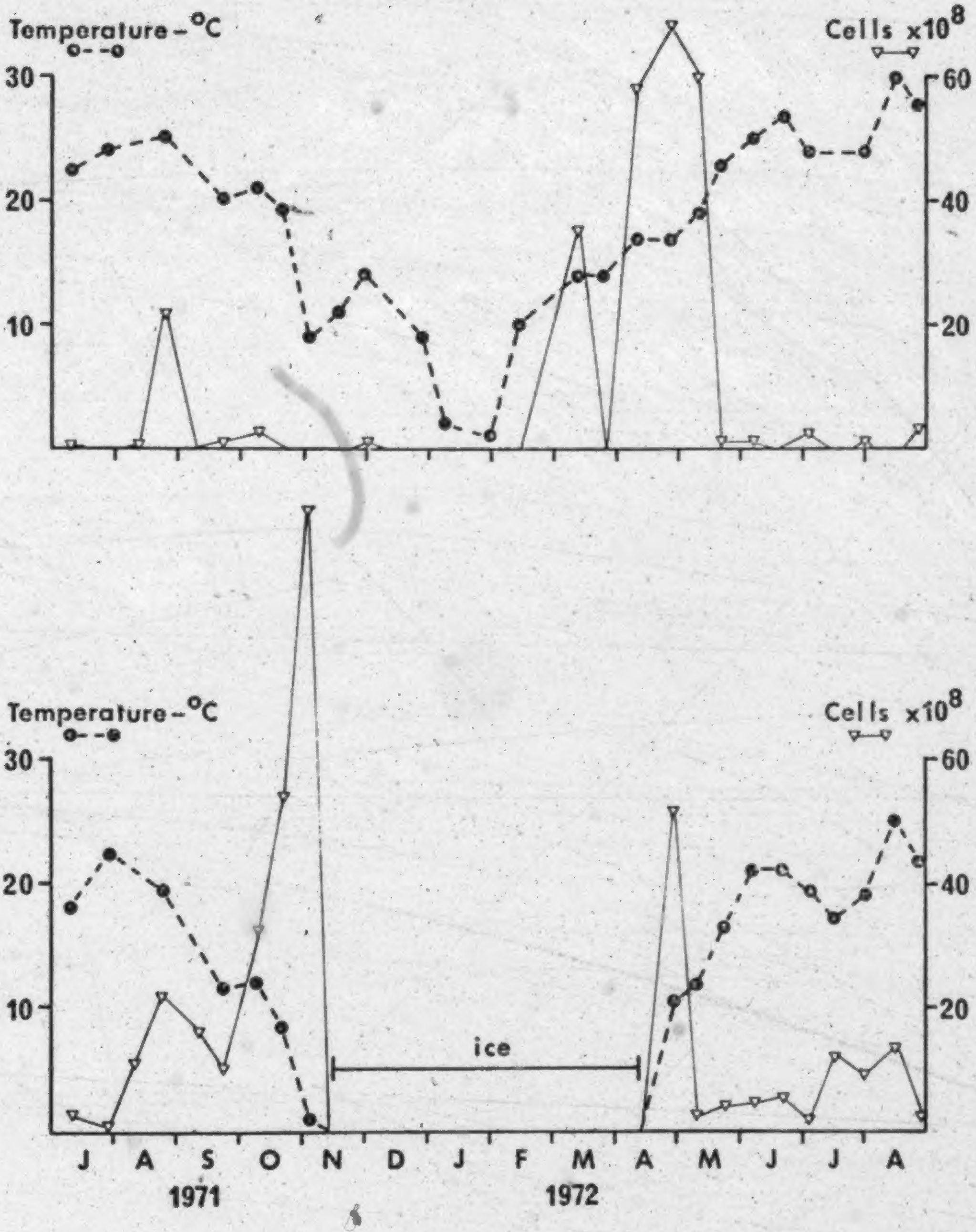
Achnanthes minutissima

A. minutissima (Figure 18) was a common member of the flora in the unheated sites, generally accounting for more than 10% of the total population. After a brief spring peak following ice break-up, the population showed an irregular increase until just prior to ice formation when the population reached its greatest size. *A. minutissima* showed a massive spring peak and then a smaller peak in the late

Heated site
(PA)

FIGURE 18. Relationship of *Achnanthes minutissima* seasonal periodicity to water temperature at a heated and a non-heated site.

Non-heated site
(WI)


Temperature - °C
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30
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40
20
Temperature - °C
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1971
1972

summer/early autumn in the heated water. During the rest of the year the population was either very low or had disappeared entirely. The temperature of 25°C appeared to be the upper tolerance limit of this species. There also appeared to be a minimum level of daylight necessary for growth as this species was not present in the heated zone during the months of December and January, although the water temperatures were well within the growth range.

Epithermia turgida

E. turgida (Figure 19) was also a major component in the flora of the unheated sites. Although this species was present through the entire open water period, it only reached a peak in late summer or early autumn. This species was recorded infrequently in the heated sites. Temperatures above 20°C appeared to be detrimental to the growth of *E. turgida*.

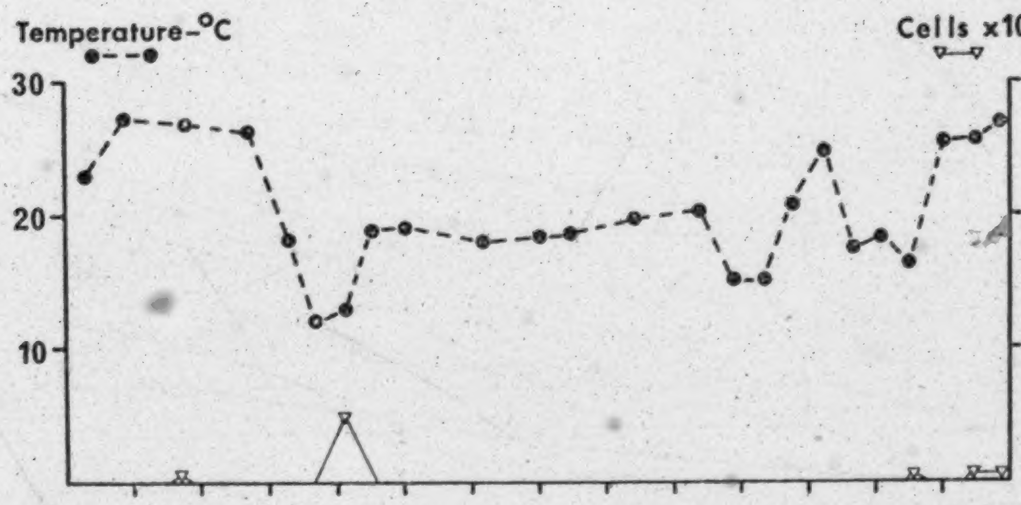
Mougeotia sp.

Mougeotia sp. at the non-heated station SI was an important member of the epiphyton from late July 1971 until ice formation in mid-November (Figure 20). There were two peaks in total cell numbers during this time, one in early September and the other in early November. In 1972 this species was first recorded in mid-July but remained a minor portion of the total population until late August when it showed an increase in cell numbers. This species was only infrequently reported in the Wabamun area control sites, but again only from late July until ice formation. The most noticeable effect of heated effluent on this species was a seasonal shift in occurrance. In unheated sites this species was confined to the late summer and autumn months, while in the heated zones it occurred only during the

Heated site
(SO)

FIGURE 19. Relationship of *Epithemia turgida* seasonal periodicity to water temperature at a heated and a non-heated site.

Non-heated site
(SI)


Temperature-°C
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Cells x10^8
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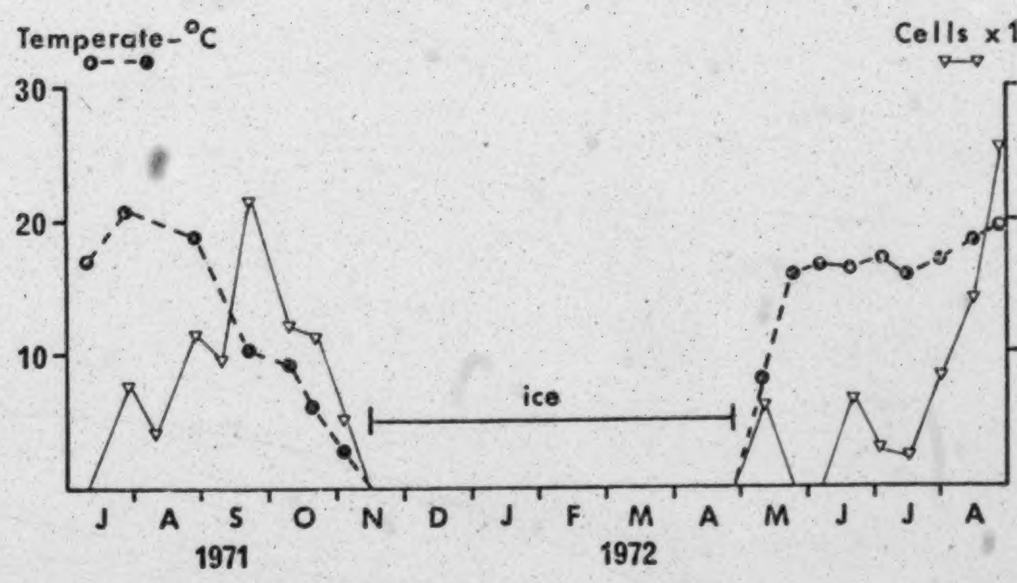
20
10
12
8
4


Temperate-°C
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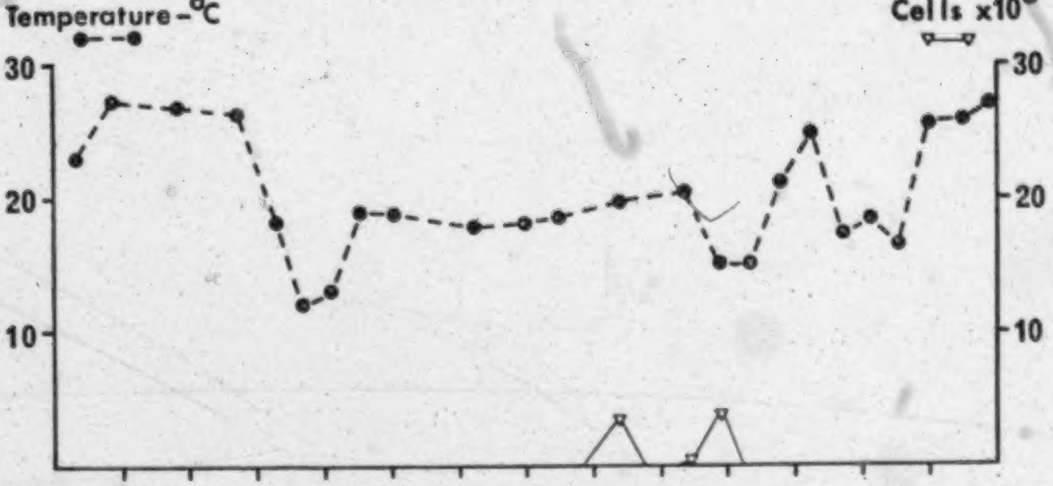
1971
1972

Heated site
(SO)

FIGURE 20. Relationship of *Mougeotia* sp. seasonal periodicity to water temperature at a heated and a non-heated site.

Non-heated site
(SI)


Temperature - °C
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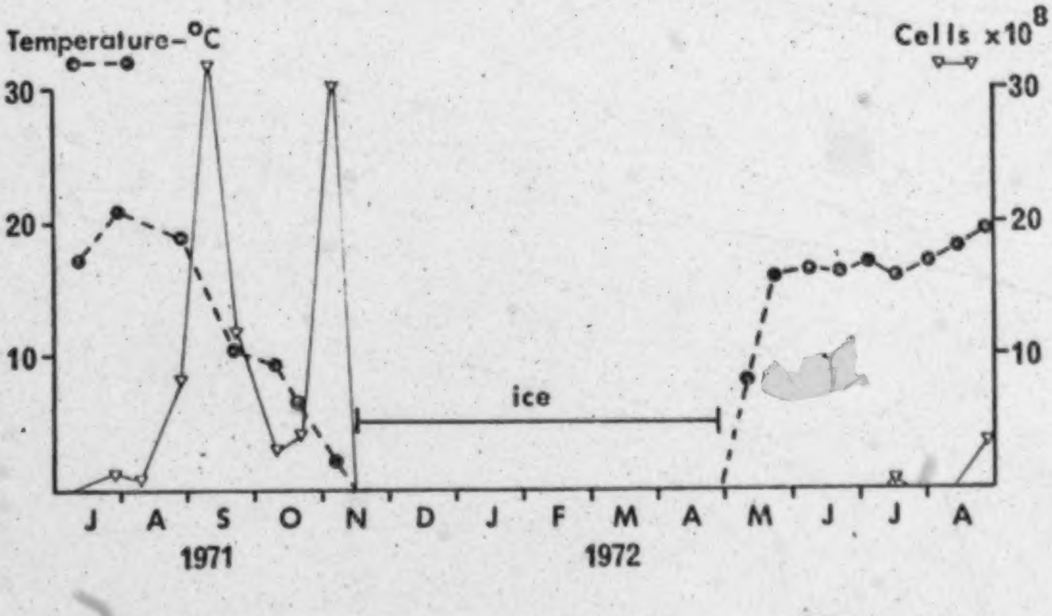
Temperature - °C
○- -●
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▽—▽
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1972

spring. As with *Epithemia turgida*, temperatures above 20°C appeared to have a detrimental effect on *Mougeotia* sp.

Oedogonium sp. and *Spirogyra* sp.

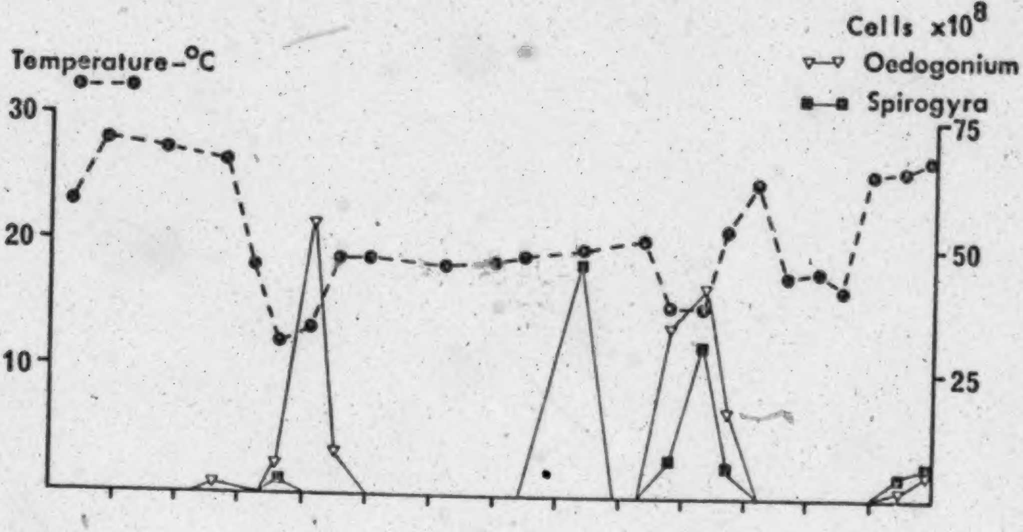
These two filamentous members of the Chlorophyta are discussed together due to the great similarity in their periodicity (Figure 21). Both species were more prevalent in heated water, with *Oedogonium* sp. being the more common of the two species. *Oedogonium* sp. occurred in the heated zone through the entire year except for mid-winter (December and January) and mid-summer (July and early August). The mid-winter absence could be due to the limited amount of light at this time. The mid-summer absence, however, was probably caused by competition from surrounding macrophyte beds for available light and nutrients as *Oedogonium* sp. was present during mid-summer at site GB, a partially heated site which was not surrounded by extensive macrophyte beds. During the year there were two peaks, one in the spring and the other in the late summer or early autumn. *Spirogyra* sp., although much less common, displayed a similar distributional pattern with a peak in the spring and again in the late summer/early autumn, the latter only observed at the heated Wabamun Station (PA) in 1971.

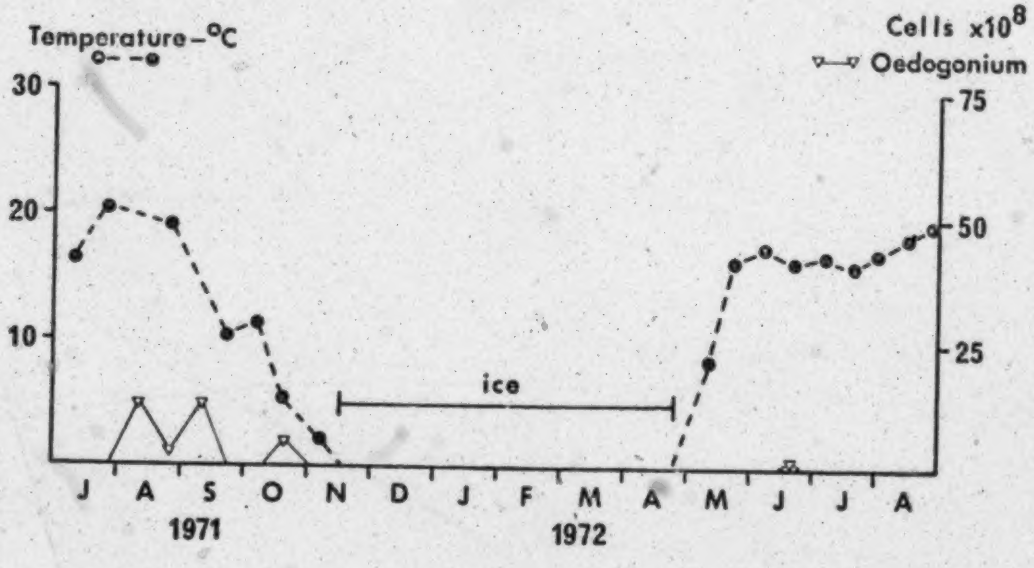
There was an increase in *Spirogyra* sp. during August, 1972, so it may be possible that the lack of the late summer/early autumn peak in 1971 was a time lag factor similar to that discussed by Cairns et al. (1972). This time factor is the period from when a pollutant enters the system until the individual species react to the pollutant. There were two distinct spring *Spirogyra* sp. peaks, but both were very close together and so were considered part of one large spring peak. *Spirogyra* sp. was never recorded in the unheated sites. Both species

Heated Site
(SO)

FIGURE 21. Relationship of *Oedogonium* sp. and *Spirogyra* sp. seasonal periodicity to water temperature at a heated and a non-heated site.

Non-heated site
(SI)


Temperature - °C
Cells x10^8
Oedogonium
Spirogyra
30
20
10
75
50
25


Temperature - °C
Cells x10^8
Oedogonium
30
20
10
75
50
25
ice
J
A
S
O
N
D
J
F
M
A
M
J
J
A
1971
1972

grew well between 15^0 and 30^{0}C, although *Oedogonium* sp. did grow below this range.

Stigeoclonium tenue

S. tenue (Figure 22) occurred primarily in the heated zone and only infrequently in the non-heated waters. This species was most common during late autumn and mid-winter and again in mid-summer. During the entire study period, this alga was primarily in a parenchymatous juvenile stage, only infrequently was it reported in the more familiar filamentous stage. *S. tenue* grew equally well at low (1-10^{0}C) as at high (20^0-30^{0}C) temperatures but only at the heated sites.

Cocconeis placentula

C. placentula (Figure 23) was present at all the sites throughout the year. However, the populations were much larger and composed a larger percentage of the total population in the heated zone. In the heated waters, although this species was present in large numbers during the winter and spring months, it was a more important member of the flora in the summer and autumn when it accounted for upwards of 50% of the total population. During the summer and autumn months *C. placentula* was rarely over 10% of the total population in the unheated waters. The one exception was site SC where, from mid-July until ice formation, this species accounted for from 18 to 45% of the total population. The reason for this exception could be the greater turbulence at site SC. This species grew well at all temperatures from 1^0 to 30^{0}C.

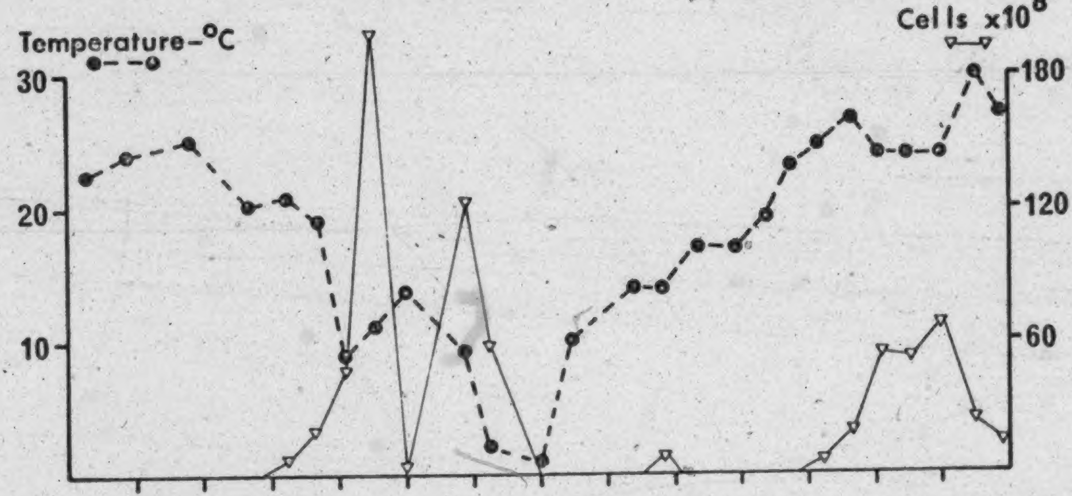
Gomphonema gracile

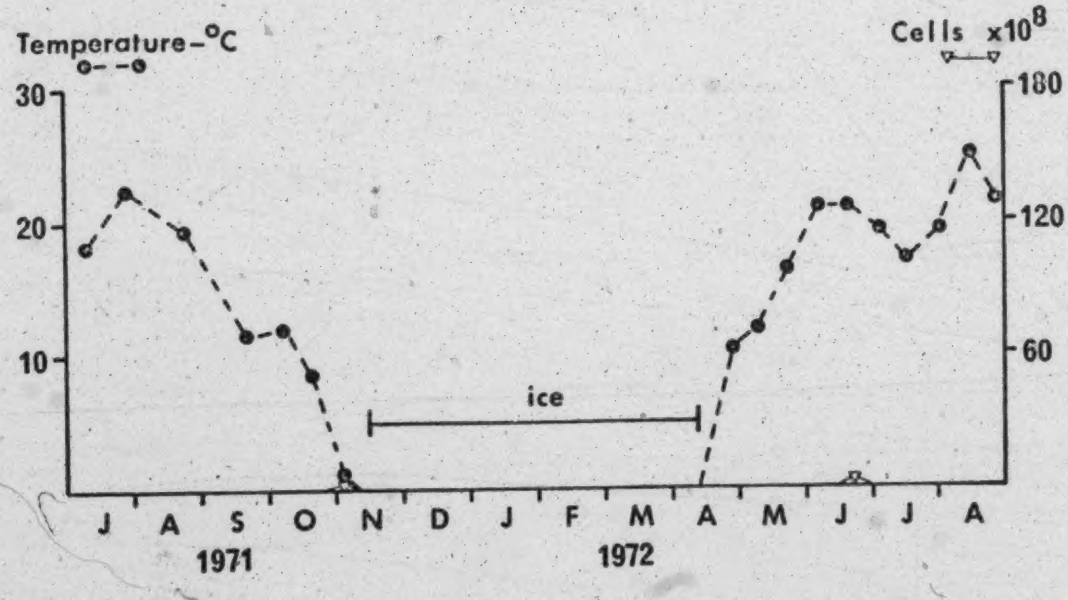
This species was also reported at all the sites throughout the

Heated site
(PA)

FIGURE 22. Relationship of *Stigeoclonium tenue* seasonal periodicity to water temperature at a heated and a non-heated site.

Non-heated site
(WI)

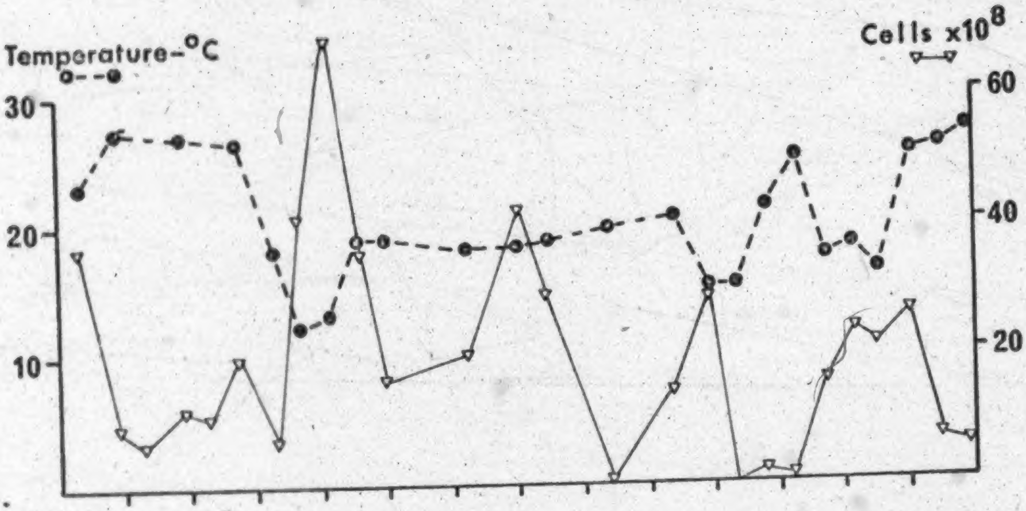

Temperature-°C
●- -●
Cells x10⁸
▽—▽
30
20
10
180
120
60

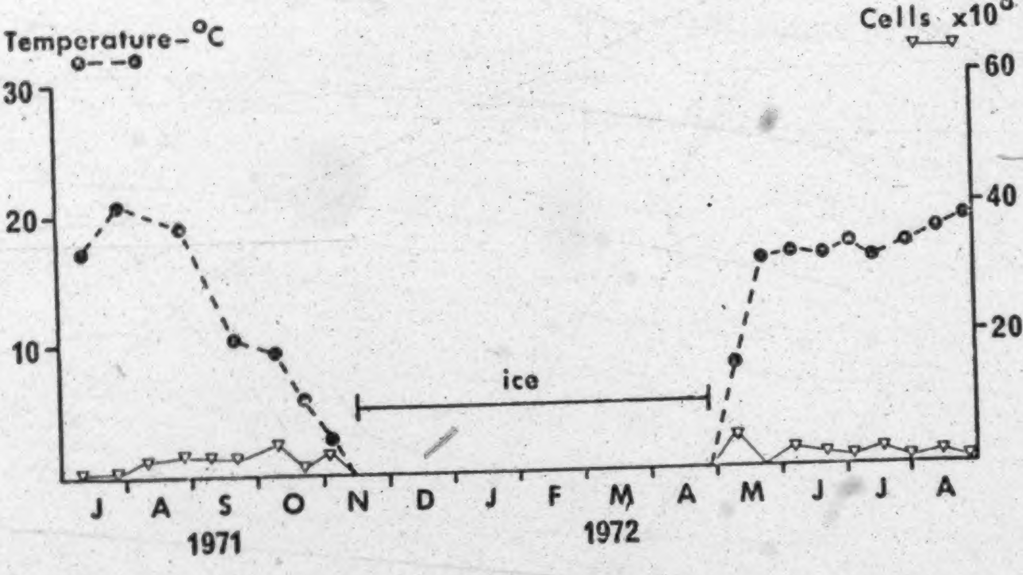

Temperature-°C
○- -○
Cells x10⁸
▽—▽
30
20
10
180
120
60
ice
J
A
S
O
N
D
J
F
M
A
M
J
J
A
1971
1972

Heated site
(SO)

FIGURE 23. Relationship of *Cocconeis placentula* seasonal periodicity to water temperature at a heated and a non-heated site.

Non-heated site
(SI)


Temperature-°C
o--●
30
20
10
Cells x10^8
▽—▽
60
40
20


Temperature-°C
o--●
30
20
10
Cells x10^8
▽—▽
60
40
20
ice
J
A
S
O
N
D
J
F
M
A
M
J
J
A
1971
1972

year but was most common in the heated water (Figure 24). During the summer and early autumn *G. gracile* was often one of the more common species in the heated zone but it was during the late autumn and winter that it attained the largest populations. From late October until late March this species ranged from 18×10^8 to 72×10^8 cells/m^2 host stem while the maximum summer population was 17×10^8 cells/m^2 host stem in the heated water. The population of this species in the unheated water seldom surpassed 10 to 12×10^8 cells/m^2 host stem although it was a common species during the summer and early autumn. *Gomphonema gracile* grew well at temperatures below 25°C.

Gomphonema parvulum

G. parvulum (Figure 25) displayed a distribution pattern very similar to that shown by *Gorphonema gracile*. The population was the largest during the autumn and winter with a major peak of 37×10^8 cells/m^2 host stem in early November in the heated sites. In the unheated waters there was a small peak immediately after ice break-up in early May and another in early June. There were other minor peaks during the late summer and in early November, just before ice formation. Although this species was found at all temperatures during the study, it appeared to grow best at temperatures below 20°C.

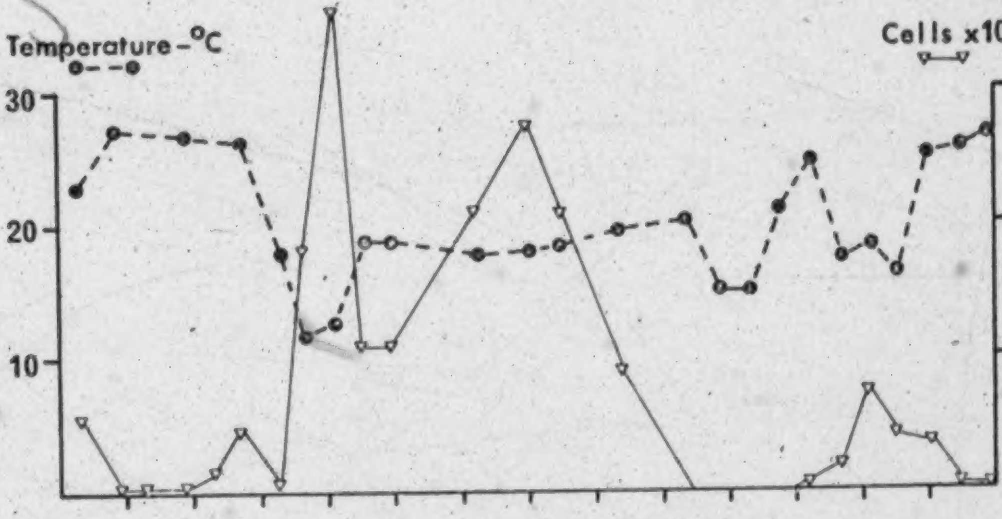
Diatoma elongatum

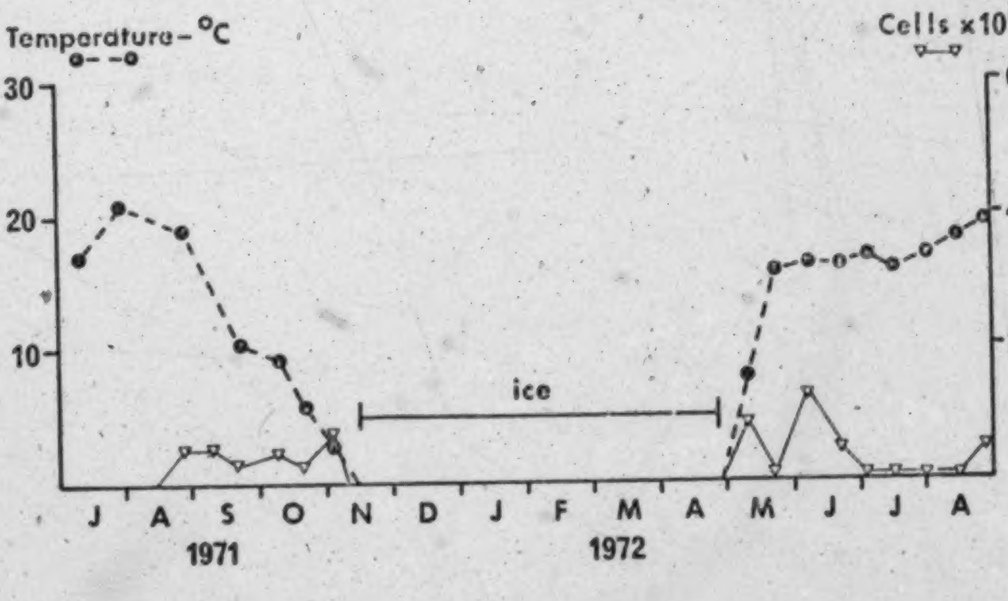
D. elongatum (Figure 26) was a cold water species, being restricted to water temperatures below 20°C, but at the same time was an important algal species in the heated sites. In the heated waters this species was generally confined to a period encompassing the months of February, March, April and May, although the population during these months was very large. It was infrequently recorded in the

Heated site
(SO)

FIGURE 24. Relationship of *Gomphonema gracile* seasonal periodicity to water temperature at a heated and a non-heated site.

Non-heated site
(SI)

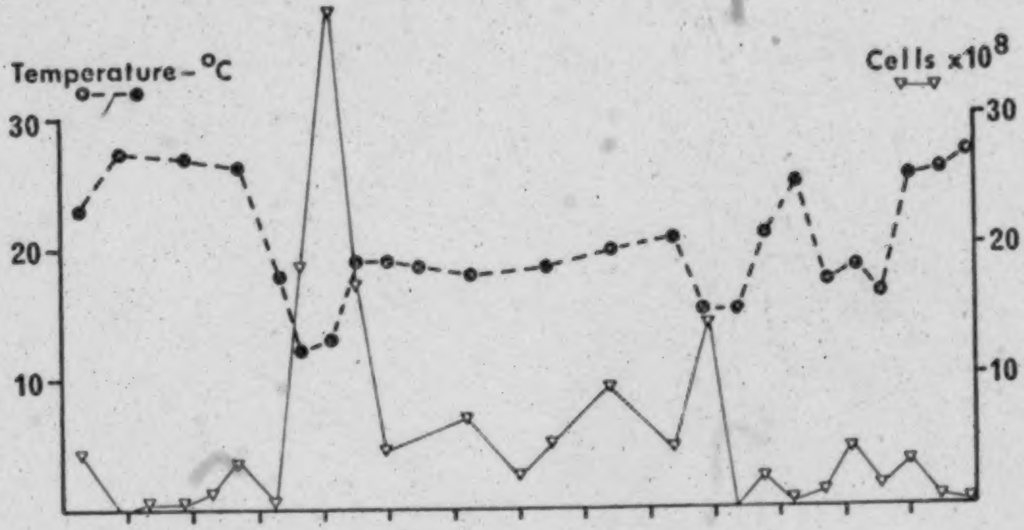

Temperature-°C
o--o
30
20
10
Cells x10^8
▽—▽
60
40
20

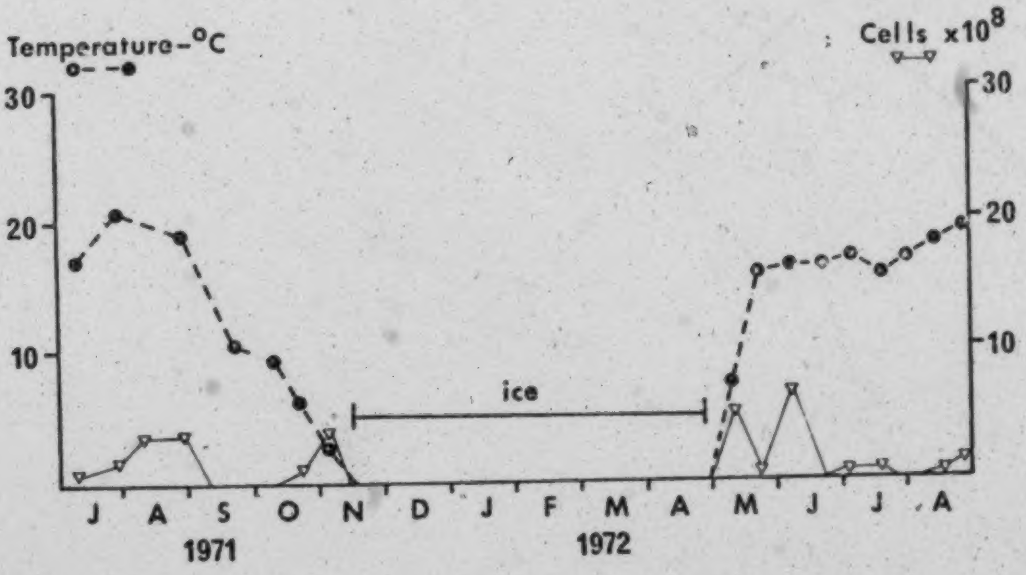

Temperature-°C
o--o
30
20
10
Cells x10^8
▽—▽
60
40
20
ice
J
A
S
O
N
D
J
F
M
A
M
J
J
A
1971
1972

Heated site
(SO)

FIGURE 25. Relationship of *Gomphonema parvulum* seasonal periodicity to water temperature at a heated and a non-heated site.

Non-heated site
(SI)

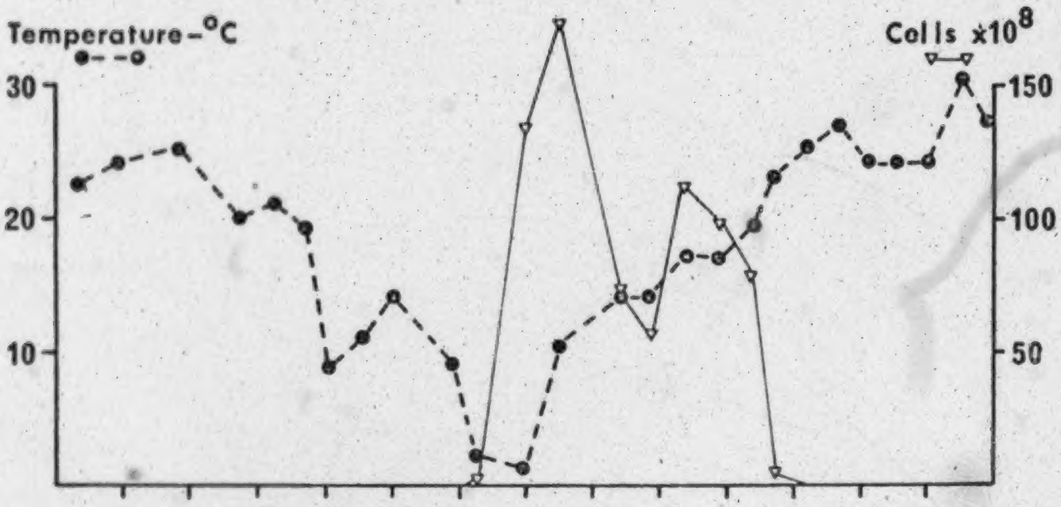

Temperature - °C
30
20
10
Cells x10^8
30
20
10

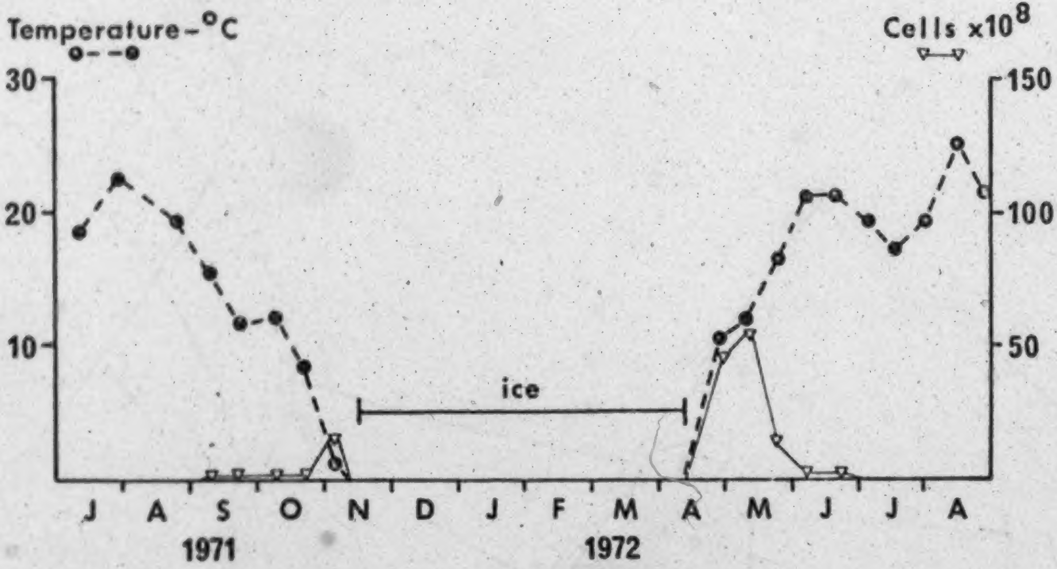

Temperature - °C
30
20
10
Cells x10^8
30
20
10
ice
J
A
S
O
N
D
J
F
M
A
M
J
J
A
1971
1972

Heated site
(PA)

FIGURE 26. Relationship of *Diatoma elongatum* seasonal periodicity to water temperature at a heated and a non-heated site.

Non-heated site
(WI)


Temperature-°C
●--○
30
20
10
Cells x10^8
▽—▽
150
100
50


Temperature-°C
○--●
30
20
10
Cells x10^8
▽—▽
150
100
50
ice
J
A
S
O
N
D
J
F
M
A
M
J
J
A
1971
1972

heated sites during the autumn. In the unheated water, however, besides the large spring peak, there was a smaller but distinct peak in the autumn, just before ice formation. The spring peak in the unheated sites was generally much smaller than that in the heated sites, perhaps due to the much shorter period of open water,as the populations in both the heated and unheated sites declined at the same time.

Fragilaria capucina

This species (Figure 27) was also restricted to the spring months of the year, occurring during the months of February through early May. *F. capucina* was usually the most common species during the spring peak at all sites. As the period of open water was much shorter in the non-heated sites, the populations were generally smaller than those in the heated sites. As with *Diatoma elongatum*, this species declined at all sites at the same time. This species was not recorded when the temperature was above 20°C.

Fragilaria vaucheriae

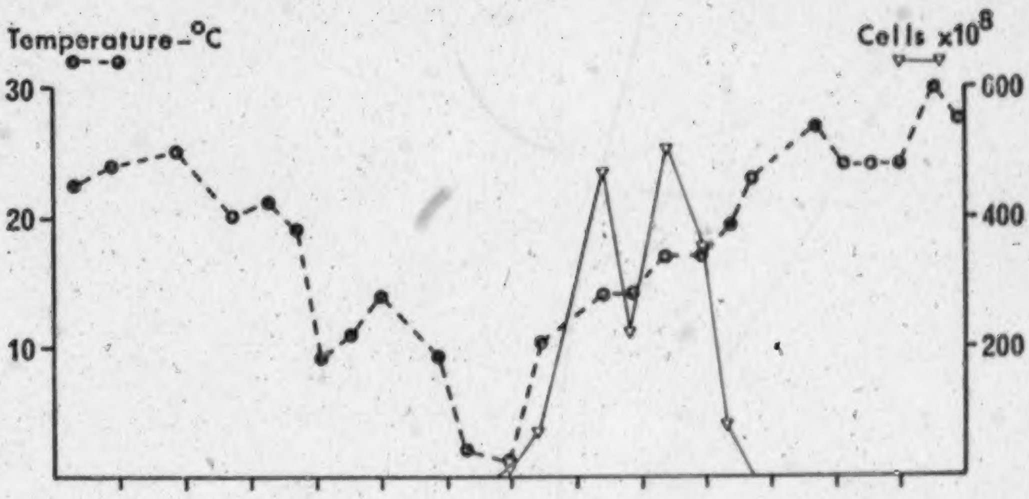
F. vaucheriae (Figure 28) was also considered a spring species although it was found irregualarly throughout the year at all sites in relatively small numbers. The spring peak was larger at the heated sites. This was due to the ice-free areas lengthening the duration of the spring peak compared with the non-heated stations. Hence, *Fragilaria vaucheriae* was able to maintain a population from January to May at the heated site but only from mid-April at the unheated site (Figure 28). The upper tolerance limit of this species appeared to be 20°C.

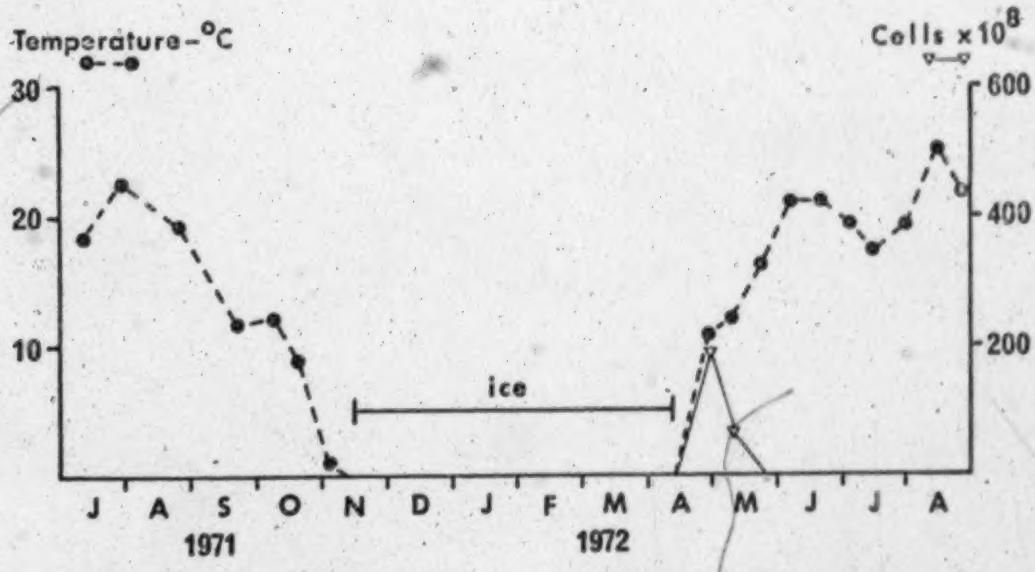
Variation in temperature between the heated and non-heated sites appeared to be an important but not the only factor in regulating population size of the species discussed above.

Heated site
(PA)

FIGURE 27. Relationship of *Fragilaria capucina* seasonal periodicity to water temperature at a heated and a non-heated site.

Non-heated site
(WI)

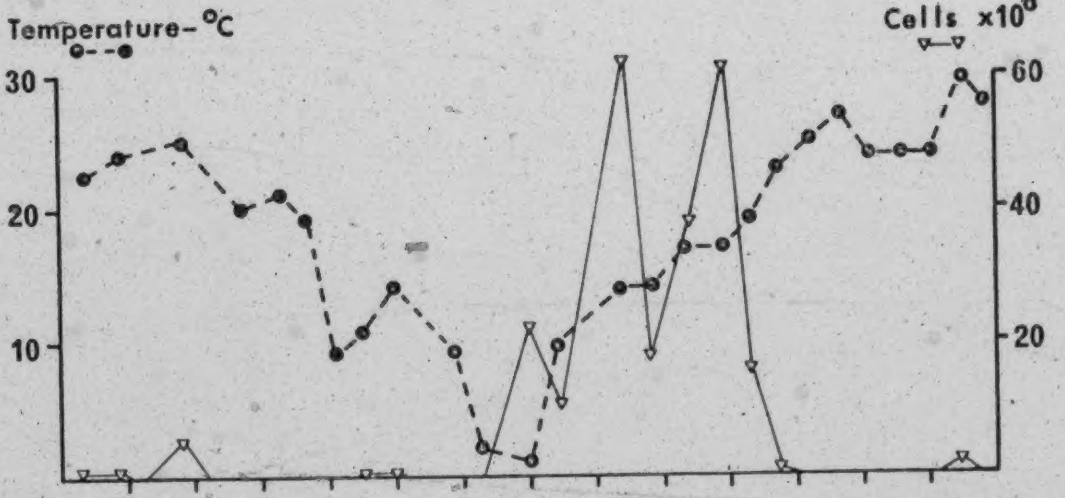

Temperature-°C
o--o
30
20
10
Cells x10^8
▽—▽
600
400
200

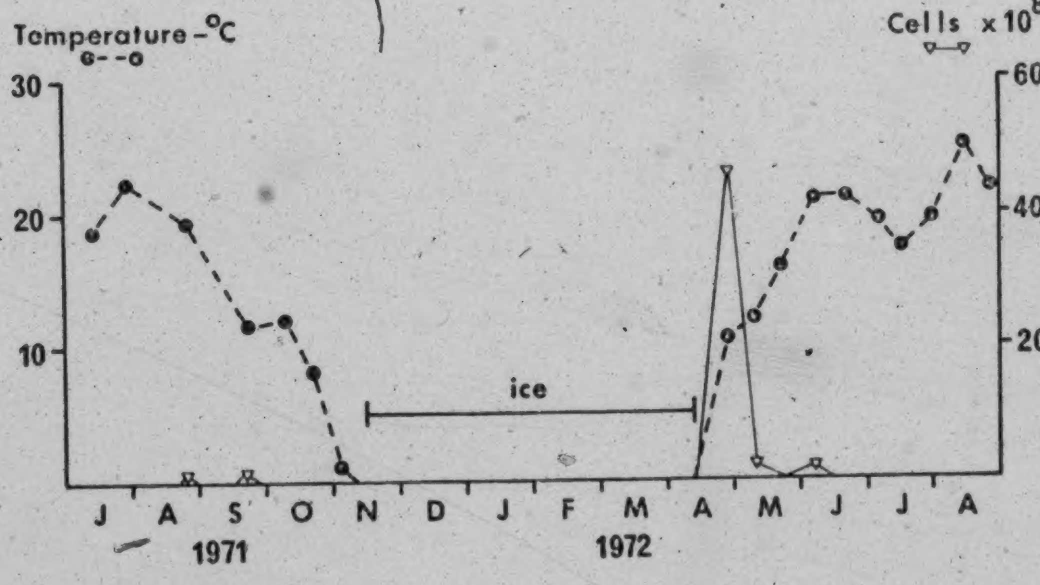

Temperature-°C
●--●
30
20
10
Cells x10^8
▽—▽
600
400
200
ice
J
A
S
O
N
D
J
F
M
A
M
J
J
A
1971
1972

Heated site
(PA)

FIGURE 28. Relationship of *Fragilaria vaucheriae* seasonal periodicity to water temperature at a heated and a non-heated site.

Non-heated site
(WI)


Temperature-°C
o--●
30
20
10
Cells x10⁸
▽—▽
60
40
20


Temperature-°C
o--o
30
20
10
Cells x10⁸
▽—▽
60
40
20
ice
J
A
S
O
N
D
J
F
M
A
M
J
J
A
1971
1972

SUMMARY

A general trend concerning the seasonal succession of the epiphytic algal flora has emerged. Immediately after ice break-up in late April, a spring maximum was recorded. During late May and June the population declined towards a summer minimum. A second peak occurred in late August or early September. Immediately after this second peak the standing crop either declined sharply or only slightly. A smaller peak was often recorded in early November just before the flora disappeared in mid-November when ice formation occurred.

The heated effluent, although it did not alter the general seasonal succession pattern of spring peak, summer minimum and autumn peak did increase the period of open water from the usual seven months to a full year in the affected areas, which caused the brief spring peak to be extended over a longer period of time. The second peak in late summer/early autumn was more sharply defined in the heated zone, with all three standing crop parameters showing a rapid decline immediately after the peak.

The relative dominance of the epiphyton was altered by the heated effluent (Table 10). In the unheated portions of the lake, the only common alga, along with diatoms, was *Mougeotia* sp. The spring maximum in both the heated and non-heated areas was dominated by *Fragilaria capucina* and *Diatoma elongatum* but population sizes were much greater in the heated areas. However, the peak in the late summer or early autumn was altered radically by the heated effluent. The dominant species in the unheated zone, *Achnanthes minutissima, Epithemia turgida* and *Gomphonema gracile* were replaced by the filamentous chlorophycean algae, *Oedogonium* sp. and *Spirogyra* sp. in the heated

TABLE 10

Relative Dominance of the Major Species at Heated and Non-heated sites during spring maximum, summer minimum and late summer/early autumn maximum

Species	Spring Maximum	Summer Minimum	Late Summer/ Early Autumn Maximum
Heated Site			
Achnanthes minutissima	C	T	C
Epithemia turgida	-	T	T
Mougeotia sp.	T	-	-
Oedogonium sp.	C	-	D
Spirogyra sp.	C	-	D
Stigeoclonium tenue	-	D	C
Cocconeis placentula	C	D	C
Gomphonema gracile	C	C	C
Gomphonema parvulum	C	T	C
Diatoma elongatum	D	-	-
Fragilaria capucina	D	-	-
Fragilaria vaucheriae	C	T	T
Non-heated Site			
Achnanthes minutissima	C	D	D
Eipthemia turgida	T	D	D
Mougeotia sp.	-	C	D
Oedogonium sp.	T	-	T
Spirogyra sp.	-	-	-
Stigeoclonium tenue	-	-	T
Cocconeis placentula	C	C	C
Gomphonema gracile	T	D	D
Gomphonema parvulum	T	C	C
Diatoma elongatum	D	-	T
Fragilaria capucina	D	-	-
Fragilaria vaucheriae	C	T	T

D = Dominant (20% of total population or greater)

C = Common (5% to 20% of total population)

T = Trace (less than 5% of total population)

- = Not recorded in population

waters. *Cocconeis placentula* and *Stigeoclonium tenue* were the most common species during the remainder of the year in the heated waters. In the unheated areas there was a much greater variety in common species throughout the year, and although *Cocconeis placentula* was common, it was seldom dominant while *Stigeoclonium tenue* was infrequently recorded.

The heated water zones have a greater mean yearly standing crop than the non-heated zones, due primarily to the longer period of open water in the former. Monthly averages between the heated and non-heated sites were often comparable.

DISCUSSION

Seasonal Succession and Standing Crop

During this study it has been found that for a reasonably complete description of the sampled population more than one method of standing crop estimation must be used. Each method has inherent errors that may significantly alter the interpretation of the standing crop if the method is used alone.

Chlorophyll a determination gives a representative picture of standing crop size; however, it gives no information on the algal components of the community (Hickman, 1973). Tippett (1969) pointed out that the use of chlorophyll a content for standing crop determination was based on two often incorrect assumptions: (1) algal cells of one species will always have the same amount of chlorophyll a per unit biomass, and (2) different algal species have proportionally the same amount of chlorophyll a per unit biomass. Sargent (1940) reported that the chlorophyll a content in *Chlorella* sp. cells grown in the sun was approximately one-half that of *Chlorella* sp. cells grown in the shade. During the course of this study it was noted that *Fragilaria capucina* (cell volume $490\mu^3$) had a much smaller chloroplast than did *Diatoma elongatum* (cell volume $300\mu^3$). This method also fails to provide information on the various algal species and their relative percentage of the total population. Findenegg (1965) emphasized the importance of species determination if an understanding of the algal community is to be obtained.

Cell counting, although a long and tedious process, does provide the information concerning species composition necessary for seasonal succession. This method, however, tends to over-emphasize the importance of the smaller algal species and correspondingly underemphasize the importance of the larger algal species. At site PA, during December 1971 there was a 100-fold increase in total cell numbers, 1.5 x 10^8 cells/m^2 host stem to 1.5 x 10^{10} cells/m^2 host stem but total cell volume increased only 24-fold while chlorophyll a content showed a 29-fold increase. This increase was primarily caused by the rapid growth of *Stigeoclonium tenue*, a small-celled alga. Finally the preservation procedure often necessary for cell enumeration destroys many of the flagellate species (Hickman, 1973). As there were no flagellates present in this study, this counting error did not bias the results.

Cell volume determination, as it is based on cell counting, provides similar information that cell counting does. However, this method tends to overestimate the importance of the larger algal species and underestimate the importance of the smaller algal species. In late August 1971 at site PA there was a rapid increase in the population size of both *Oedogonium* sp. and *Spirogyra* sp. (both large celled species) which caused a 240-fold increase in total volume. At the same time there was only a 56-fold increase in total cell numbers and a 42-fold increase in chlorophyll a content. By overestimating the larger-celled species, it is possible to mask a population increase of a smaller species. In early September 1971 at site SI an increase in *Mougeotia* sp. was accompanied by a small decrease in *Oedogonium* sp. Both total cell numbers and chlorophyll a content recorded a standing crop increase; however, total cell volume showed a two-fold decrease.

Although each of the three methods introduces error in standing crop determinations, together they provide a fairly complete description of the sampled algal community and its various components. Chlorophyll a content provides a fast and convenient method for obtaining total standing crop size. Both total cell volume and total cell numbers complement each other, since an overestimation of a species in one of the methods is counteracted by an underestimation in the other.

Previous studies concerning seasonal succession in the epiphytic algal communities have been limited in number, and so it has been necessary to refer to work that was done on other attached communities, primarily the periphytic community. However, direct comparison between the periphyton and the epiphyton must be viewed with reservation as Tippett (1969, 1970) has demonstrated that the two are often not compatible.

The general pattern of succession as determined in this study was a spring maximum and a late summer/early autumn maximum with an intervening summer minimum. The spring maximum, which occurred immediately after ice break-up, was very short as the population immediately decreased in size to a summer minimum. After the late summer/early autumn peak the population either declined back to pre-peak minimum levels or decreased only slightly. A smaller autumn peak was often recorded immediately before ice formation.

Godward (1937) and Jørgensen (1957) have reported that the spring maximum in a natural community was generally larger than the late summer/early autumn peak. In this study, however, two of the three unheated sites, SI and SC, had larger late summer/early autumn peak while only one site, WI, showed a larger spring peak. The difference between this and previous studies may have been caused by the relatively late ice break-up at Lake Wabamun. At site GB where the ice melted in late March, a month earlier than sites SI and SC, the spring maximum was larger than the autumn maximum. At site WI the ice disappeared two weeks earlier than the other two sites; this longer period of open water may have been responsible for the spring maximum being larger than the autumn maximum. The lake studied by Godward (1937) was sampled throughout the year; however, sampling could not be begun until mid-April on those studied by Jørgensen (1957). In the three sites affected by the thermal effluent at Lake Wabamun the total cell numbers were much larger during the spring peak. The autumn peak generally showed a larger chlorophyll a content due to a dominance of large cell chlorophycean species which have a higher chloroplast area/cell ratio than do the dominant spring species, particularly *Fragilaria capucina*.

The spring bloom of an epilithic algal community did not occur until the water temperature had risen above 13°C (Castenholz, 1960). Cannon et al. (1961), however, reported that the epiphytic species *Tabellaria flocculosa* began growth only after a minimum temperature of 6°C had been reached. During this study the temperature increase during the spring was very rapid at the unheated sites and the water temperature was above 6°C but below the 13°C limit suggested by Castenholz (1960) when the first sample was taken. The standing crop at this time was usually large; therefore, the minimum temperature for growth was below 13°C. Only at site GB was the temperature below 6°C when the sampling program began. As the initial population of spring dominants was quite high, it appears that if there is a minimum temperature level for growth it is below 4°C which was the water temperature at GB when the first sample was collected.

Dillard (1969) reported that a water temperature of 15°C was important in the initiation of successional changes. In the Lake Wabamun study, however, neither the decline of the spring species nor the growth of the summer species corresponded with this or any single temperature. Usually the spring population in the unheated sites was rapidly declining before a temperature of 15°C was reached. However, a peak of spring dominants occurred in early June, 1972 at site SI when the temperature was above 15°C. At the heated sites, the spring dominants reached maximum populations when the temperature was above 15°C. It appears that some factor(s) other than temperature alone is (are) responsible for the decline of the spring dominants and the subsequent growth of the summer population.

The spring maximum at all seven sites was dominated by *Fragilaria capucina* and *Diatoma elongatum*. *Diatoma elongatum* has previously been reported as a dominant spring species (Castenholz, 1960, Tippett, 1969). *Diatoma vulgare*, another very common spring species (Castenholz, 1960), was not reported in the flora of the unheated sites, although it was a common species in the spring flora of the heated and semi-heated sites. Light may have been a determining factor for *Diatoma vulgare* as this species had reached a maximum in early April and was either rapidly declining or had already disappeared by the time the ice broke at the three unheated sites.

The common summer species at the unheated sites included *Achnanthes minutissima*, *Gomphonema gracile*, *Epithemia turgida*, and in late summer, *Mougeotia* sp. *Achnanthes minutissima* had been previously classified as a summer species with an autumn maximum (Jørgensen, 1957). Godward (1937) reported that *Epithemia turgida* showed very little seasonal variation; however, Castenholz (1960) concluded that it was primarily a summer species. At the three unheated sites in this study, *Epithemia turgida* would be classified as a summer species with an autumn peak. Godward (1937) reported that *Mougeotia parvula* was common to reed swamps during the summer but disappeared in late September. In this study, *Mougeotia* sp. appeared in the non-heated sites during the late summer and was a common species until ice formation in mid-November. *Mougeotia* sp. was only found briefly at the heated sites in the spring. *Epithemia turgida* was only infrequently found at the heated sites during the summer. *Achnanthes minutissima* and *Gomphonema gracile*, although present during the summer, reached maximum population sizes at the heated site during the winter or early spring.

Castenholz (1960) reported that an autumn peak of epilithic diatoms occurred only after the water temperatures had dropped below 15°C. During the late summer/early autumn peak at the unheated sites, the water temperature was very close to this temperature; however, the increase in population size was often initiated in late August when the water temperature was near its summer maximum. The late summer/early autumn peak in the heated zones occurred at maximum (30°C) water temperatures. This autumn peak in the unheated zones was dominated by summer species as had been previously reported by Castenholz (1960). In the heated sites, however, this peak was dominated by species that were not in the flora until just prior to the peak and that disappeared immediately after the peak.

Castenholz (1960) and Hickman (in press) reported that during the autumn, with decreasing water temperatures, some of the spring dominants reappeared in the flora. In this study, *Diatoma elongatum* was an example of such a species. At the non-heated sites, it was often present in small numbers through the summer and autumn and reached a small peak just prior to ice formation. However, spring dominants were never reported during the autumn months in the three heated sites.

Although both standing crop and species diversity were adversely affected by the increased turbulence at site SC, the general pattern of succession discussed above was not changed. Site SC was established in an area where human disturbance was maximal. Due to the many boating activities in the area this site was exposed to more turbulence than either of the other two control sites. Young (1945) showed that turbulence affected standing crop by decreasing the species diversity and floral composition, particularly in shallow areas where waves produced a surf, and hence, the turbulence was great compared to deep waters. Fox et al. (1969) concluded that turbulence affected the epiphyton by making attachment difficult for some genera and by knocking epiphyton off, thus reducing the total numbers and species diversity. At site SC, the species diversity was not noticeably affected. However, there was an increase in the relative importance of *Cocconeis placentula*, a species that attaches an entire valve face to the host macrophyte (Patrick, 1948). Filamentous species were not normally reported at this site since *Mougeotia* sp., the most common filamentous species at the unheated sites, was reported here only once.

Young (1945) also noticed a similar lack of filamentous species at exposed sites.

Effects of Thermal Effluent on the Epiphyton

Cairns et al. (1972) proposed that thermal effluent was a pollutant and could be examined as such. If the heated discharge is a pollutant in Lake Wabamun, then it should cause (1) a decrease in the number of species, and (2) a predominance of one or more species in the affected areas (Patrick et al. 1954, Cairns et al., 1972). Using an equal number of specimens from a heated and a non-heated station, it was seen that the non-heated site normally had a greater number of species: site PA, 10 species, and site WI, 14 species on August 10, 1971; site PA, 7 species, and site WI, 15 species on July 17, 1972; site PA, 12 species, and site WI, 18 species on October 19, 1971. During the summer minimum one or two species heated water sites. At site SO, *Cocconeis placentula* accounted for 81% of the total population on August 26, 1971, while at site PA, *Cocconeis placentula* accounted for 94% of the total population on July 27, 1971. During this period, the non-heated sites normally did not have one species that accounted for more than 50% of the total population; for example, at site SI, no species accounted for more than 10% of the total population on July 17, 1972. Similarly, on July 17, 1972, *Achnanthes minutissima* accounted for only 37% of the total population at site WI. This study thus confirms the proposal by Cairns et al. (1972) that in Lake Wabamun the thermal effluent was a pollutant. However, this method of species diversity determination should be viewed with reservation. It is possible that many rare species were overlooked and so the estimated diversity was low, especially when one species accounted for more than 60% to 70% of the total population.

During the winter, even when the water temperature at the heated sites had declined to within the range of normal spring temperatures there was still the marked decline in number of species: (Site WO 5 species on December 29, 1971; site SO, 7 species on February 1, 1972; site PA, 9 species on November 30, 1971). Coutant (1966) reported a similar decrease in species diversity during the winter months.

During the spring maximum at the heated sites, however, there was an increase in species diversity and a corresponding decrease in the predominance of one species, for example, on April 11, 1972 at site WO there were 16 species present and *Fragilaria capucina* comprised 49% of the total population. At this time the heated sites most closely resembled normal lake sites since the water temperatures were still within the range of normal lake summer temperatures and light levels were approaching summer levels (Hutchinson, 1957). These conditions may have been responsible for the increasing diversity. However, Young (1945) and Kowalczewski (1965) have found that there is generally a greater diversity of epiphytes on the older dead stems than on the live stems. At this time, most of the stems in the heated zone were dead. Young (1945) pointed out that the dead stems have lost their smooth waxy surface, leaving a rough surface that provides a better substratum to which the epiphyton can adhere. The increase, therefore, could be due to the better substratum provided by the dead stems.

Early work on the biotic effects of a thermal effluent (Cairns, 1956) showed that there was a population shift from a predominance of members of the Bacillariophyta to that by members of the Chlorophyta at approximately 30°C. Later workers (Ventakerwarku, 1969; Pucher-Petovic, 1970) reported that this shift in dominance was correlated with dissolved oxygen levels, a high oxygen content favoring members of the Chlorophyta and a low oxygen content favoring members of the Cyanophyta. In this study during the months of July, August, and early September, the water temperatures approached 30°C, and the oxygen levels were very high, well above 100% saturation level. As would be expected from the work of Cairns (1956), Ventakeswarku (1969), and Pucher-Petovic (1970) there was an influx of chlorophycean species, particularly *Oedogonium* sp. and *Spirogyra* sp., which were common at this time. These two species were either infrequent or absent at the non-heated sites during the entire study.

Patrick et al. (1969) reported that a temperature increase above the ambient up to 29°-30°C caused an increase in biomass. Such an increase was not observed in the heated zones as all three parameters recorded comparable standing crops at both the heated and non-heated sites during the ice free months. It is possible that other environmental factors, particularly competition from surrounding macrophytes in the heated sites masked this increase.

As the thermal effluent caused only a slight increase in the water temperatures at site GB, this site would be expected to have a flora that was intermediate between that of the unheated and the heated sites (Owen, 1960). Members of the Chlorophyta were more common at this site than at the unheated sites, but they never became important members of the population. Both *Spirogyra* sp. and *Bulbochaeta* sp. were recorded at this site but not at the unheated sites. There was no noticeable decline in species diversity at site GB. Members of the Cyanophyta were more common at this site than at anyof the other six sites. Although Owen (1960) reported an increase in the Cyanophyta in thermally affected areas, this was not the cause of the larger cyanophycean population at this site, since no large cyanophycean populations occurred at the heated sites. These populations were due to other unknown factors.

The major effect of the thermal effluent, however, was to increase the growth period from seven months to a full twelve months. This longer growing season was responsible for the large spring maximum in the heated sites. The previous year's *Scirpus* sp. stems were not destroyed by ice and so provided a substratum for the epiphyton. The large spring maximum often stretched over a two month period as there was little competition from surrounding aquatic macrophytes for either space or nutrients.

Many of the common algal species showed a thermal preference. Some of these species were restricted to either the heated or unheated sites and appeared in the other only infrequently while other species grew well in either type of site.

Achnanthes minutissima

A. minutissima was most common in the unheated sites although it did grow well at the heated sites, particularly during the spring. Ventakeswarku (1969) reported that *A. minutissima* preferred low water temperatures and high dissolved oxygen levels. As would be expected from previous studies, this species was most common immediately prior to ice formation when the water temperature was below 5°C and the dissolved oxygen level was near 100% saturation. This species could be classified as a eu-eurytherm (Hustedt, 1956) as it grew over a temperature range. However, the best growth occurred below 15°C.

Epithemia turgida

E. turgida experienced optimal growth between 10°C and 20°C and so could be considered a tropical cold water meso-stenotherm (Hustedt, 1956). It was reported that this species showed little seasonal variation although there was a slight increase from September through December (Godward, 1937). Castenholz (1960), however, concluded that this species was a major summer species with an autumn peak. At lake Wabamun *E. turgida* was a major summer species and reached a peak in September. The small peak in the heated zone occurred when the temperature dropped below 15°C.

Mougeotia sp.

Mougeotia sp. could be classified as a cold water stenotherm (Hustedt, 1956) with major growth occurring below 15°C. This species was a major autumn species in the non-heated zones; however, in the heated sites it was a spring species. During the spring, the heated sites, as stated previously, most closely resembled the non-heated sites. It is this close approximation to late summer conditions in a non-heated site that may have caused the seasonal shift. *Mougeotia parvula* was a common species from April to early July in the reed swamps examined by Godward (1937). *Mougeotia* spp. were found in the same lake; however, growing from June to December with a maximum in September (Godward, 1937). It is possible that, as with the study of Godward (1937), there could be two or more different species of *Mougeotia* in the lake. However, this is unlikely because the vegetative structure was virtually identical for all specimens. Identification to species was not possible as conjugating cells were never seen.

Oedogonium sp. and *Spirogyra* sp.

Both *Oedogonium* sp. and *Spirogyra* sp. were considered to be meso-eurytherms (Hustedt, 1956) as growth occurred most frequently between the temperatures of 15° and 30°C. There were two peaks for both species, one in the late summer/early autumn and the other during the spring maximum in April. Godward (1937) reported that *Spirogyra* sp. reached a peak during the winter, although it was present in his study during the summer at depths below 4m, hence under conditions of low light intensity. Venkateswarku (1969) also reported that *Spirogyra* sp. was adversely affected by high temperature. Castenholz (1960), however, found that *Spirogyra* sp. was common during the summer. Dillard (1969) reported that a *Spirogyra* sp. - *Oedogonium* sp. community was common during the late spring and summer months. Godward (1937) and Abdin (1949) reported that *Oedogonium* sp. had a summer maximum as this species preferred high light intensities. Hickman (1971) reported that *Oedogonium* was common from February until June and during August and September. This distributional pattern was very similar to that shown by both *Oedogonium* sp. and *Spirogyra* sp. at Lake Wabamun.

Stigeoclonium tenue

S. tenue grew well through a wide range of temperatures. However, it was only infrequently recorded in the non-heated sites. Venkateswarku (1969) reported that it was adversely affected by high temperatures, but this seems unlikely as a peak was recorded during mid-summer when water temperatures were approaching 30°C. Light levels may have been the determining factor in the distributional patterns of this species. Abdin (1949) reported that *S. tenue* preferred moderate light levels and was inhibited by high light levels. The large peak in the late autumn and early winter occurred when the light levels were low. By mid-summer, the *Scirpus* sp. beds had collected a large amount of floating debris. This debris and the dense surrounding macrophyte beds reduced the light intensity reaching the epiphyton to a level where *Stigeoclonium tenue* was not inhibited. Lack of debris and dense macrophyte beds could have prevented the growth of *S. tenue* at the non-heated sites.

Cocconeis placentula

C. placentula grew well through the entire temperature range in this study. This species apparently favored the heated sites although it occurred at all sites. Godward (1937) reported that this species was found throughout the year with a maximum in December. Fox et al. (1969) found a similar distributional pattern; however, both Jørgensen (1957) and Castenholz (1960) reported an autumn maximum for species. Light intensity also appears to be a major factor in the distribution of this species as Tippett (1969) reported that *C. placentula* was inhibited by high light intensities. The smaller populations in the non-heated zones could have been due to a lack of surface debris necessary to lower the light intensity during the summer months. Unlike *Stigeoclonium tenue*, the growth of this species appearedto be only retarded and not totally inhibited by summer light intensities at Lake Wabamun.

Gomphonema gracile

The growth of *G. gracile* appeared to be reduced above 25°C. During the periods of maximum water temperature the population size was very low in the heated sites. No literature was found that pertained to either the seasonal periodicity or environmental requirements of this species.

Gomphonema parvulum

G. parvulum grew well below 25°C, although it did occur in warmer waters in very small numbers. Wallace (1955) reported that the optimal growth temperature was 22°C, however, it would grow in culture at temperatures up to 34°C. The upper thermal limit in culture is often much higher than in nature because of a lack of competition in the former. In nature, a species may be eliminated by an unfavorable but not lethal factor due to the competition from other species for space and nutrients (Cairns, 1956). It would appear that a temperature of above 25°C was unfavorable for this species. The cause of the limited growth at the unheated sites is unknown. However, it may be related to the preference shown by *G. parvulum* (Butcher, 1932) for water having a high organic content. Foerster et al. (1965) reported that organic compounds appeared to be in greater concentrations in weed beds that in open water. As the heated sites were surrounded by dense beds of aquatic macrophytes, there would be a greater amount of organic matter released from the macrophytes at the heated sites (Allen, 1971). Due to these dense beds, there would also be less turbulence to disperse the organic compounds throughout the water column.

Diatoma elongatum

D. elongatum experienced optimal growth below 20°C. Previous workers (Butcher, 1932, Godward, 1937, Castenholz, 1960) have reported that this species was restricted to the cooler water periods and often reached large populations during the spring. At all sites there was a large spring peak, but only at the non-heated sites was there a smaller autumn peak immediately prior to ice formation. Tippett (1969) also found a small population peak in this species during the autumn. In this study the chemical parameters were above the minimum necessary for growth as reported by Tippett (1969): nitrate, .015 mg/l, orthophosphate, 0.0009 mg/l, and silica 0.5 mg/l.

It would appear, then, that either light and/or temperature would be the factor initiating the rapid decline during late spring. The decrease in population size in the unheated sites occurred at temperatures that were lower than the temperatures at which maximal growth occurred in the heated sites. From this it was concluded that temperature was not the factor. As all seven sites showed a decline at the same time, it is proposed that light was this limiting factor.

Fragilaria capucina

F. capucina was also a spring species that showed no growth above 20°C. No literature was found that pertained to either the seasonal periodicity or environmental requirements of this species.

Fragilaria vaucheriae

F. vaucheriae was another species that grew best during the spring. All the major growth peaks of this species occurred at temperatures below 20°C, although it was reported at higher temperatures. Castenholz (1960) classified *F. vaucheriae* as a summer species and Evans and Stockner (1972) also reported that it was a common summer species.

Although many of the species did show a preference for either the heated or non-heated sites, it was generally not possible to cite temperature as the reason for this preference. The environmental changes brought about by the influx of thermal effluent were more complex than simply an increase in temperature.

Dissolved Inorganic Ions and the Algal Community

Seasonal trends in silica, nitrate, and orthophosphate were observed in the heated sites.

Silica

Silica levels showed an irregular increase during the autumn and winter (Appendix A, Tables 3, 4, 7). These increases in silica appeared to be associated with the dissolution of silica from the previous year's stems, along with dissolution of planktonic and benthic diatoms in the sediment. Jørgensen (1957) showed that the dissolution of the planktonic and benthic diatoms in the sediment was rapid while that of the stems was more gradual. During the spring there was a rapid decline in silica concentration. Two of the three heated sites showed an increase in the total cell numbers of diatoms along with the decrease in silica concentration as had been previously reported for a planktonic diatom (Lund, 1950). Site SO, however, showed a decrease in the total cell numbers of diatoms along with the decrease in silica concentration. No reason for this abnormality can be suggested from the data available. Perhaps in this area the planktonic and other benthic diatom populations were increasing and utilizing the available silica. A depletion of silica is acknowledged (Lund, 1950, Jørgensen, 1957) as an important, if not the prime factor, in the cessation of the spring diatom bloom. The minimum level of silica at which diatom growth can occur was reported as 0.03 to 0.04 mg/l (Jørgensen, 1957), although Knudson (1957) found that growth in *Tabellaria flocculosa* stopped when silica concentrations were less than 0.5 mg/l. At Lake Wabamun, however, the silica levels were generally above 1.5 mg/l and only once did the concentration drop below 1.0 mg/l at any of the seven sites. It would appear that silica was not a limiting factor during this study.

Nitrate

Nitrate levels were also higher during the winter than during the summer. This would be expected as the rate of nitrification is higher and the biological demands for nitrate are lower during the winter (Hutchinson, 1957). The spring decline in nitrate coincided with the drop in silica at the two heated sites in the Wabamun area but occured two weeks after the decline in silica at site SO. The decline in nitrate levels at all three of the heated sites occurred as total cell numbers were increasing. Godward (1937) reported that nitrate levels were generally lower in extensive reed beds than in open water because of the more rapid use of nitrate and the slower oxidation of organic matter in the reed beds. This apparently was not the case at Lake Wabamun as the summer nitrate levels at both the dense sedge beds in the heated areas and the open sedge beds in the non-heated areas were comparable. When nitrate is limiting there is competition between the host macrophyte and its associated epiphyton (Fitzgerald, 1969) with a corresponding exclusion of the epiphyton. There is no data available concerning nitrate limitation, as it is determined from nitrate assimilation rates. However, an exclusion of the epiphyton was never observed, so it appears that nitrate was not limiting.

Orthophosphate

Trends in orthophosphate levels were less distinct as the concentrations were usually below the level detectable by the first method employed. Orthophosphate, however, was present in higher levels during the winter. The drop in orthophosphate occurred sometime during the spring maximum. Brown and Austin (1973) reported an increase in total cell numbers along with the decrease in orthophosphate. The lowest phosphate level recorded was 0.001 mg/l., a concentration above the phosphate levels found by Tippett (1969) as sufficient for algal growth. The average levels were between 0.002 and 0.004 mg/l, within the mean range given by Hutchinson (1957) as representatives of lakes of the world.

None of these three nutrients appeared to be limiting. Both silica and orthophosphate levels were above previously recorded minimum levels for growth. There was apparently no evidence of the exclusion of epiphyton that would be expected if nitrate was limiting.

Conclusions

The influx of thermal effluent caused many changes in the affected areas. The increased period of open water resulted in a larger standing crop in the heated areas. This thermal effluent brought about a decline in species diversity and a corresponding increase in the predominance of a few species, and so could be considered a pollutant (Patrick et al., 1954). At the heated sites during the period of maximum water temperature there was an influx of chlorophycean species. Many of the common species showed a preference for either heated or non-heated sites although this preference normally did not correspond with a change in temperature alone. This preference, however, was caused ultimately by an influx of thermal effluent as the nutrient levels at all the sites were comparable. Therefore, the effect of the thermal effluent upon this epiphytic algal community was a complex situation as all variations between the heated and the non-heated sites appeared to be related in one way or another to the input of heated water.

SUMMARY

1. All seven sampled sites displayed the same general trend in seasonal succession; a spring peak, a summer minimum, and then another major peak in late summer/early autumn. Often a small peak occurred during the late autumn. In this study the relative size of the two major peaks apparently was related to the time of ice break-up. At sites SC and SI, where the break-up was recorded in late April, the late summer/early autumn peak was larger; however, at sites WI and GB, where the ice break-up was earlier, the spring peak was larger. Such a relationship was not observed in the heated sites due to an influx of filamentous chlorophycean algae during the late summer/early autumn peak.

2. The heated effluent did not alter the general pattern of seasonal succession although it caused a change in the composition of the flora. This change was most pronounced during the late summer/early autumn peak when water temperatures were highest. During this time the heated discharge increased water temperatures to a level where there was a shift of dominance from diatoms to chlorophycean species, as had been predicted by previous workers. *Achnanthes minutissima*, *Epithemia turgida*, and *Gomphonema gracile*, the dominant species in the non-heated sites were replaced by *Oedogonium* sp. and *Spirogyra* sp. at the heated sites during this late summer/early autumn peak.

3. The thermal effluent was considered a pollutant at Lake Wabamun as it caused a decrease in the number of species and a corresponding increase in the relative importance of a few species. Only during the spring maximum, when conditions at the heated sites most closely resembled normal lake conditions, did the species diversity

and predominance of the major species approach normal lake proportions. However, this increase in diversity may have only been a result of growth on dead stems.

4. The major consequence of the thermal discharge was an increase in the period of open water at the affected sites. The mean yearly standing crop was higher in the heated sites since the period of growth was extended from seven months to a full twelve months, although corresponding monthly averages between heated and non-heated sites were comparable. The spring maximum was extended over a two-month period in the heated sites while it was often confined to less than two weeks in the non-heated sites.

5. Many of the common species displayed a preference for either the heated or the non-heated sites. This preference often could not be correlated with an increase in water temperature alone as the influx of thermal effluent caused many other environmental changes. However, the ultimate cause of this preference was the influx of the thermal effluent.

6. Silica, nitrate, and orthophosphate showed a seasonal pattern, especially in the heated sites. All three were present in higher concentrations over the winter and showed a marked decline during the spring epiphyton maximum. At no time during the study, however, did any of these three nutrients appear to be limiting.

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APPENDIX A

CHEMICAL PARAMETERS OF THE SEVEN SAMPLED SITES

TABLE 1

Chemical parameters of site SC

	Free Carbon Dioxide - mg/l	Hydrogen Ion Concentration	Alkalinity Total - mg/l	Alkalinity Phenol - mg/l	Hardness Total - mg/l	Hardness Calcium - mg/l	Orthophosphate mg/l	Nitrate mg/l	Silica mg/l	Iron mg/l	Sulfate mg/l	Chloride mg/l	Fluoride mg/l	Potassium mg/l	Manganese mg/l	Filterable Dissolved Solids mg/l	Conductance (micromhos)	Turbidity (JTU)	Color
July 28,1971	0.4	8.89	155.5	12.0	140	44	0.004	0.03	1.5	0.04	27	2.13				209.6	329	9	12
Sept. 9		8.89	170.3	9.8	105		<0.05	0.04	2.0	0.02	18	12.0	0.25				370	7	
Sept. 21	0.45	8.80	145.7	10.8	132	32	0.002	0.03	1.5	0.05	27	2.13				236.0	320	11	42
Oct. 5	0.7	8.68	155.9	9.0	93		<0.05	0.03	1.6	0.02	19	2.37				210.1	355	11	
Oct. 19	1.5	8.40	156.5	1.55	98		<0.05	0.05	2.8	0.08	20	1.52	0.48			241.4	350	11	
April 27,1972	0.75	8.80	180.5	16.5	130	65	<0.05	0.02	2.7	0.06	18	0.11				222.6	380	2	25
May 9	0.3	9.00	124.1	13.0	96	28	0.03	0.02	8.4	0.12	40	1.42				256.0	320	12	12
May 23	0.45	8.90	166.2	17.5	120	54	0.003	0.02	1.5	0.04	31	0.96		0	0.040	190.6	340	21	6
June 6	0.6	8.81	169.0	14.5	152	62	0.014	0.03	1.7	0.05	29	2.84				130.0	355	6	12
June 20	0.4	8.82	134.0	12.0	100	34	0.005	0.02	1.6	0.08	27	0.71				205.0	280	22	51
July 4	0.6	8.75	162.4	8.4	172	46	0.002	0.04	1.8	0.06	30	2.84		0	0.040	251.6	340	10	15
July 17	1.0	8.53	157.3	5.0	120	50	<0.05	0.02	1.7	0.08	22	0.96				138.8	350	6	42
Aug. 1	0.6	8.73	156.3	7.3	104	44	0.006	0.03	3.4	0.06	32	1.77				208.2	350	17	55
Aug. 15	0.1	9.44	173.8	21.8	142	58	<0.05	0.02	2.5	0.02	17	0.96				214.2	390	4	50
Aug. 29	0.5	8.81	153.7	12.9	104	42	0.007	0.03	3.0	0.05	31	1.77				164.2	340	18	37

TABLE 2

Chemical parameters of site WI

	Free Carbon Dioxide - mg/l	Hydrogen Ion Concentration	Alkalinity Total - mg/l	Alkalinity Phenol - mg/l	Hardness Total - mg/l	Hardness Calcium - mg/l	Orthophosphate mg/l	Nitrate mg/l	Silica mg/l	Iron mg/l	Sulfate mg/l	Chloride mg/l	Fluoride mg/l	Potassium mg/l	Manganese mg/l	Filterable Dissolved Solids mg/l	Conductance (micromhos)	Turbidity (JTU)	Color
Apr.28,1971		9.37	127.6	18.5	96	32	0.02	0.02	1.9	0.14	64	3.90				306.1	350	14	15
May 11		9.00	126.8	1.1	104	32	0.002	0.02	1.05	0.05	30	1.77				254.0	330	21	15
May 27		9.05	147.4	15.0	112	34	0.019	0.02	2.5	0.08	31	4.25				320.0	320	13	20
July 28		8.88	153.0	7.8	124	40	0.003	0.03	1.4	0.05	25	2.13					330	10	30
Sept. 9		8.78	175.9	8.7	114		<0.05	0.03	2.2	0.02	15	5.0	0.26				375	6	17
Sept. 21	0.8	8.71	165.5	10.0	124	46	0.002	0.02	1.6	0.10	28	2.84				296.0	340		
Oct. 5	<0.1	9.72	171.3	28.3	97		<0.05	0.04	2.2	0.05	19	2.43	0.39			193.0	360	10	
Oct. 19	1.5	8.47	149.0	2.05	90		<0.05	0.03	1.8	0.05	20	1.38	0.47			230.4	300	15	
Nov. 3	0.7	8.85	152.0	5.5	108	41	<0.05	0.04	2.9	0.08	19	0.35				171.1	320	12	10
Apr.27,1972	0.8	8.78	186.5	16.0	134	63	<0.05	0.03	2.0	0.05	13	1.6				244.8	400	1	12
May 9	1.0	8.62	167.1	4.35	108	68	0.006	0.03	1.3	0.05	31	1.45				268.4	400	2	6
May 23	0.6	8.81	165.5	6.0	148	58	0.004	0.03	1.5	0.04	29	2.13		0	0.040	119.4	355	7	15
June 6	0.2	9.15	160.5	16.0	136	56	0.002	0.03	1.6	0.04	32	2.84				70.4	339	9	15
June 20	1.3	8.48	162.7	4.7	128	52	0.004	0.02	1.5	0.02	31	2.41		0	0.031	167.4	370	7	25
July 4	0.3	9.05	163.3	16.2	140	48	0.01	0.03	1.5	0.06	32	2.13				323.0	340	17	20
July 17	0.5	8.79	147.1	6.6	112	38	<0.05	0.03	3.0	0.09	19	0.96				290.0	326	10	20
Aug.1	0.2	9.32	162.0	20.0	120	52	0.012	0.03	2.6	0.05	27	3.19				289.4	338	8	15
Aug. 15	0.3	9.12	177.2	13.5	128	62	<0.05	0.02	2.5	0.04	18	0.96				129.6	380	3	38
Aug.29	0.6	8.77	161.0	9.0	104	34	0.01	0.04	3.5	0.05	30	2.84				136.4	340	18	37

TABLE 3

Chemical parameters of site PA

	Free Carbon Dioxide - mg/l	Hydrogen Ion Concentration	Alkalinity Total - mg/l	Alkalinity Phenol - mg/l	Hardness Total - mg/l	Hardness Calcium - mg/l	Orthophosphate mg/l	Nitrate mg/l	Silica mg/l	Iron mg/l	Sulfate mg/l	Chloride mg/l	Fluoride mg/l	Potassium mg/l	Manganese mg/l	Filterable Dissolved Solids mg/l	Conductance (micromhos)	Turbidity (JTU)	Color
May 27,1971		8.65	155.0	5.4	108	36	0.015	0.02	1.1	0.10	29	3.19				202.3	340	27	25
July 28		9.36	159.5	23.5	88	28	0.02	0.03	1.4	0.05	32	2.48					350	18	15
Sept. 9		8.96	173.0	11.4	105		<0.05	0.03	2.3	0.05	17	11.0	0.27				370	8	25
Sept. 21		9.21	155.3	4.9	132	50	0.004	0.03	1.7	0.05	26	3.19					350	8	25
Oct. 5	<0.1	9.70	160.1	36.2	94		0.05	0.03	1.2	0.03	24	1.50	0.33			191.0	320	12	
Oct. 19	1.7	8.32	164.7	0.45	96		0.09	0.05	2.2	0.06	21	1.70	0.38			215.1	310	11	
Nov. 3	0.5	8.85	176.0	12.5	130	59	<0.05	0.02	2.4	0.08	16	1.06				233.1	380	9	10
Nov. 16	0.1	9.48	187.5	25.0	122	56	0.06	0.03	2.4	0.08	18	1.06				225.5	370	8	10
Nov. 30	1.1	8.61	185.6	5.4	136	66	0.025	0.03	2.5	0.05	33	1.42				260.8	390	44	20
Jan.7,1972	1.2	8.74	199.2	11.0	200	72	0.009	0.03	2.7	0.05	34	1.77				203.2	400	4	15
Feb. 1	0.5	9.11	204.8	21.1	152	58	0.025	0.03	3.1	0.05	37	2.13				432.6	420	7	20
Feb. 13	0.8	9.21	145.3	23.0	124	24	0.009	0.04	3.0	0.05	34	2.84				158.6	340	22	12
March 12	0.7	8.75	194.0	15.0	132	66	0.05	0.05	2.6	0.04	19	2.09				358.8	420	4	6
March 25	0.4	9.10	194.4	24.8	134	67	<0.05	0.06	2.9	0.04	20	2.09				314.6	390	6	4
April 11	0.2	9.22	178.4	30.3	138	53	<0.05	0.03	1.6	0.04	24	2.41				242.0	360	6	25
April 27	0.3	9.08	182.0	21.0	132	64	<0.05	0.02	2.0	0.06	17	1.70				272.0	390	2	25
May 9	0.7	8.69	161.5	7.9	124	44	0.001	0.02	1.5	0.05	31	1.42				218.0	340	13	15
May 23	0.3	9.01	157.5	7.5	120	50	0.004	0.03	1.5	0.04	29	2.84		0	0.031	67.6	339	5	15
June 6	0.3	8.90	138.0	12.0	96	26	0.01	0.02	1.5	0.05	32	1.77				186.0	320	16	15
June 20	0.4	8.79	151.0	9.9	112	44	<0.05	0.02	1.3	0.05	36	1.45		0	0.040	250.4	340	10	50
July 4	0.6	8.70	166.5	10.5	152	48	0.002	0.03	1.5	0.04	31	3.19				288.0	360	9	15
July 17	0.9	8.48	164.0	3.7	120	52	<0.05	0.03	2.0	0.04	18	2.16				223.6	358	66	25
Aug. 1	0.02	9.31	166.0	20.0	116	54	0.004	0.03	2.5	0.05	29	1.77				163.8	339	11	15
Aug. 15	0.2	9.31	173.8	20.9	124	64	<0.05	0.02	2.5	0.08	17	0.71				163.6	390	5	48
Aug. 29	0.2	9.15	167.0	18.4	124	60	0.005	0.03	3.7	0.05	28	2.41				179.8	340	6	22

TABLE 4

Chemical parameters of site WO

	Free Carbon Dioxide - mg/l	Hydrogen Ion Concentration	Alkalinity Total - mg/l	Alkalinity Phenol - mg/l	Hardness Total - mg/l	Hardness Calcium - mg/l	Orthophosphate mg/l	Nitrate mg/l	Silica mg/l	Iron mg/l	Sulfate mg/l	Chloride mg/l	Fluoride mg/l	Potassium mg/l	Manganese mg/l	Filterable Dissolved Solids mg/l	Conductance (micromhos)	Turbidity (JTU)	Color
Oct. 19,1971	0.9	8.51	156.0	4.0	90		0.06	0.06	1.8	0.03	19	3.68	0.35			237.9	340	8	
Nov. 3	0.4	8.91	173.0	16.5	142	48	<0.05	0.02	2.3	0.06	18	1.05				244.7	360	10	10
Nov. 16	<0.1	9.70	183.0	32.5	125	48	<0.05	0.04	2.4	0.07	18	0.71				319.1	360	7	
Nov. 30	0.6	8.81	191.8	12.5	144	64	0.004	0.02	2.5	0.05	33	1.42				296.4	400	2	15
Jan.7,1972	0.4	9.11	182.9	24.9	148	58	0.030	0.04	3.3	0.05	34	3.90				203.2	360	19	12
Feb. 1	0.4	9.07	197.5	23.5	176	64	0.24	0.04	3.0	0.05	34	3.90				393.8	420	5	20
Feb. 13		8.97	144.9	15.2	104	24	0.007	0.04	3.1	0.06	34	2.13					320	30	8
March 12	0.5	8.91	194.7	15.9	136	67	<0.05	0.06	2.7	0.04	19	3.30				328.0	405	7	3
March 25	0.4	9.02	195.5	17.0	152	68	<0.05	0.06	3.0	0.06	20	2.66				357.0	380	10	4
April 11	0.2	9.30	182.3	22.3	120	56	<0.05	0.02	1.8	0.02	22	2.91		0		199.4	380	7	25
April 27	0.7	8.70	182.0	10.5	126	65	<0.05	0.03	22	0.08	17	0.11				299.0	400	2	22
May 9	0.6	8.70	140.3	5.8	88	28	0.002	0.02	1.5	0.05	31	1.77		0	0.014	201.6	320	14	26
May 23	0.4	8.94	168.4	14.8	128	68	0.006	0.02	1.9	0.04	32	2.41				191.8	360	8	4
June 6	0.4	8.79	128.0	7.8	92	28	0.02	0.02	1.7	0.05	24	0.71		0	0.014	226.6	270	20	8
June 20	0.5	8.81	156.9	10.7	116	46	0.01	0.02	1.6	0.04	31	8.77				214.4	360	14	25
July 4	0.2	9.12	141.4	16.2	136	30	0.005	0.03	1.6	0.07	31	2.84				164.6	300	17	25
July 17	0.6	8.67	158.7	6.6	108	38	<0.05	0.03	2.1	0.03	15	0.96				211.6	340	7	23
Aug. 1	0.4	8.92	146.7	14.0	104	38	0.005	0.03	2.1	0.05	30	2.84				229.0	330	17	48
Aug. 15	<0.1	9.70	168.4	31.9	120	56	<0.05	0.02	1.7	0.04	17	1.70				140.0	360	2	50
Aug. 29	0.5	8.78	164.3	10.8	104	40	0.02	0.04	3.5	0.05	29	1.77				169.5	350	18	42

TABLE 5

Chemical parameters of site 5I

	Free Carbon Dioxide - mg/l	Hydrogen Ion Concentration	Alkalinity Total - mg/l	Alkalinity Phenol - mg/l	Hardness Total - mg/l	Hardness Calcium - mg/l	Orthophosphate mg/l	Nitrate mg/l	Silica mg/l	Iron mg/l	Sulfate mg/l	Chloride mg/l	Fluoride mg/l	Potassium mg/l	Manganese mg/l	Filterable Dissolved Solids mg/l	Conductance (micromhos)	Turbidity (JTU)	Color
July 28, 1971	0.2	9.19	146.0	19.1	92	46	0.003	0.04	1.2	0.05	28	1.77				220.2	300	14	30
Sept. 9		9.00	169.0	10.0	108	45	<0.05	0.02	2.3	0.06		1.06				181.3	340	8	
Sept. 21	0.4	9.06	171.9	9.1	128	58	0.002	0.02	1.5	0.06	26	1.77				293.4	380	5	15
Oct. 5	0.4	9.04	158.6	9.6	90		<0.05	0.02	1.6	0.05	18	1.70	0.37			219.7	340	5	
Oct. 19	1.8	8.37	160.9	1.2	90		<0.05	0.03	1.7	0.02	21	1.88				226.4	330	9	
Nov. 3	0.6	8.90	175.5	14.5	128	56	<0.05	0.02	2.3	0.06	17	1.06				243.1	370	5	10
May 9, 1972	0.6	8.83	147.2	8.8	112	36	0.005	0.04	1.8	0.05	32	2.48				203.6	290	10	30
May 23	1.1	8.56	182.1	7.3	136	66	0.002	0.02	2.0	0.06	32	0.96				308.4	380	16	4
June 6	0.3	9.05	164.0	15.5	128	52	0.024	0.05	1.5	0.05	32	1.77		0	0.025	233.8	340	11	15
June 20	0.3	9.13	160.0	13.5	128	54	0.003	0.02	1.2	0.04	29	1.77				165.6	342	10	25
July 4	0.6	8.75	162.5	9.2	120	50	0.02	0.02	1.5	0.06	32	2.13				253.6	340	11	15
July 17	1.0	8.54	160.9	4.7	128	44	<0.05	0.03	1.9	0.04	20	0.96		0	0.050	291.6	330	6	31
Aug. 1	0.8	8.63	163.1	10.5	112	50	0.003	0.02	2.5	0.05	31	0.96				260.8	340	18	20
Aug. 15	0.2	9.27	178.9	16.7	138	68	<0.05	0.01	2.5	0.02	17	1.45				75.8	380	4	35
Aug. 29	0.4	8.95	174.6	17.0	136	62	0.004	0.02	3.2	0.05	27	1.95				196.6	380	5	20

TABLE 6

Chemical parameters of site GB

	Free Carbon Dioxide - mg/l	Hydrogen Ion Concentration	Alkalinity Total - mg/l	Alkalinity Phenol - mg/l	Hardness Total - mg/l	Hardness Calcium - mg/l	Orthophosphate mg/l	Nitrate mg/l	Silica mg/l	Iron mg/l	Sulfate mg/l	Chloride mg/l	Fluoride mg/l	Potassium mg/l	Manganese mg/l	Filterable Dissolved Solids mg/l	Conductance (micromhos)	Turbidity (JTU)	Color
May 27,1971		8.78	164.6	9.7	136	46	0.007	0.02	0.6	0.06	27	0.71				329.1	350	12	25
July 28	0.2	9.18	141.4	14.4	92	34	0.002	0.03	2.0	0.05	33	0.71				216.5	300	15	48
Sept. 9		9.10	173.8	16.4	110		<0.05	0.04	2.2	0.02	16	6.0	0.30				370	9	
Sept. 21	0.2	9.30	167.0	23.0	140	60	0.03	0.04	2.4	0.08	36	1.42				252.0	350	11	48
Oct. 5	0.5	8.90	165.4	6.7	103		<0.05	0.05	2.2	0.08	30	1.65	0.41			227.0	340	18	
Oct. 19	1.0	8.65	152.9	5.9	102		<0.05	0.06	2.3	0.09	27	6.31	0.36			254.0	350	10	
Nov. 3	0.7	8.85	166.0	13.5	134	66	<0.05	0.09	2.8	0.10	38	1.06				265.4	390	17	45
Apr. 11,1972	0.7	8.70	117.1	6.0	96	71	0.21	0.05	2.7	0.10	24	0.46				202.0	290	11	152
Apr. 27	1.0	8.55	145.5	3.5	108	53	<0.05	0.05	2.6	0.08	20	0.35				272.6	340	4	50
May 9	0.4	8.78	95.1	1.6	104	32	0.007	0.06	1.4	0.07	37	1.77				208.0	280	13	70
May 23	0.9	8.60	172.4	5.3	128	64	0.002	0.02	1.7	0.06		1.95				212.w	370	4	20
June 6	0.6	8.72	153.0	7.0	100	34	0.009	0.02	1.7	0.05	31	1.77		0	0.028	230.0	330	14	12
June 20	0.6	8.71	148.7	11.1	116	50	0.003	0.03	1.0	0.04	31	1.45				254.8	340	12	25
July 4	0.5	8.73	144.5	14.0	136	44	0.02	0.02	1.5	0.08	36	2.13		0	0.050	156.2	340	12	42
July 17	0.3	8.89	141.3	8.0	96	36	<0.05	0.04	1.5	0.05	27	1.21		0	0.030	261.6	320	10	50
Aug. 1	0.2	9.17	161.5	17.0	112	48	0.002	0.03	2.5	0.04	28	2.13				165.8	342	5	25
Aug. 15	0.2	9.27	165.3	18.4	112	58	<0.05	0.04	2.1	0.04	21	1.21				169.2	360	4	52
Aug. 29	0.3	9.07	156.0	13.0	100	26	0.01	0.04	2.2	0.05	32	1.77				152.9	340	22	30

TABLE 7

Chemical parameters at site SO

	Free Carbon Dioxide - mg/l	Hydrogen Ion Concentration	Alkalinity Total - mg/l	Alkalinity Phenol - mg/l	Hardness Total - mg/l	Hardness Calcium - mg/l	Orthophosphate mg/l	Nitrate mg/l	Silica mg/l	Iron mg/l	Sulfate mg/l	Chloride mg/l	Fluoride mg/l	Potassium mg/l	Manganese mg/l	Filterable Dissolved Solids mg/l	Conductance (micromhos)	Turbidity (JTU)	Color
May 11,1971		8.91	145.5	9.5	112	28	0.001	0.02	1.03	0.05	31	1.42				254.0	280	26	15
July 28		9.14	142.8	17.1	92	30	0.002	0.03	1.3	0.05	28	3.19					300	15	62
Sept. 9		9.10	173.0	19.0	110		<0.05	0.03	2.0	0.05	18	8.00	0.25				360	5	17
Sept. 21	0.2	9.27	174.0	20.6	120	58	0.001	0.03	1.9	0.08	29	1.77				272.4	350	8	15
Oct. 5	0.2	9.19	173.3	13.3	45		<0.05	0.04	1.6	0.05	17	1.55	0.37			206.4	360	11	
Oct. 19	1.1	8.56	156.9	4.4	100		<0.05	0.03	1.8	0.05	28	1.38				247.4	340	5	
Nov. 3	0.5	8.88	158.0	10.0	99	34	<0.05	0.04	2.3	0.06	18	0.71				237.0	340	10	10
Nov. 16	<0.1	9.56	179.0	30.0	122	54	0.15	0.06	2.4	0.10	17	1.06				227.9	350	7	
Nov. 30	0.3	9.17	189.0	14.8	132	70	0.006	0.02	2.2	0.05	33	2.13				280.2	390	3	15
Jan.7,1972	0.4	8.95	181.0	16.1	148	48	0.026	0.02	2.5	0.05	34	2.84				232.4	370	17	15
Feb. 1	0.5	8.95	189.6	14.0	152	58	0.18	0.04	2.5	0.06	34	3.90				274.8	400	5	20
March 12	0.5	8.93	192.2	18.6	134	62	0.07	0.07	2.8	0.04	21	2.00				265.6	390	2	3
Apr. 11	0.2	9.20	181.0	20.0	140	67	<0.05	0.07	2.3	0.05	24	3.16				233.2	380	5	25
Apr. 27	0.7	8.75	180.0	19.0	140	63	<0.05	0.02	1.9	0.12	16	2.48				272.0	380	1	22
May 9	0.8	8.60	150.4	7.9	108	48	0.008	0.03	1.5	0.08	31	2.41				165.0	340	20	22
May 23	0.9	8.60	174.2	9.8	120	68	0.004	0.02	2.0	0.04	32	1.45				262.4	360	2	6
June 6		8.60	149.5	3.5	124	58	0.002	0.03	1.6	0.08	32	1.42		0	0.040		362	8	15
June 20	0.4	8.93	145.1	14.7	108	40	0.001	0.03	1.1	0.05	31	1.77				198.0	320	17	30
July 4	0.5	8.80	156.8	10.0	152	46	0.009	0.03	2.3	0.24	37	2.84		0	0.060	325.8	340	22	56
July 17	1.0	8.51	169.5	4.5	100	52	<0.05	0.03	1.9	0.04	18	1.21		0	0.039	223.0	341	6	25
Aug. 1	0.4	8.94	172.5	11.5	124	62	0.009	0.03	2.7	0.04	28	1.77				288.8	360	8	15
Aug. 15	0.3	9.08	179.9	12.2	122	67	<0.05	0.01	2.7	0.04	17	0.96				117.2	400	4	25
Aug. 29	0.4	8.83	140.1	11.0	84	26	0.005	0.02	3.4	0.05	29	2.13				101.6	300	19	30